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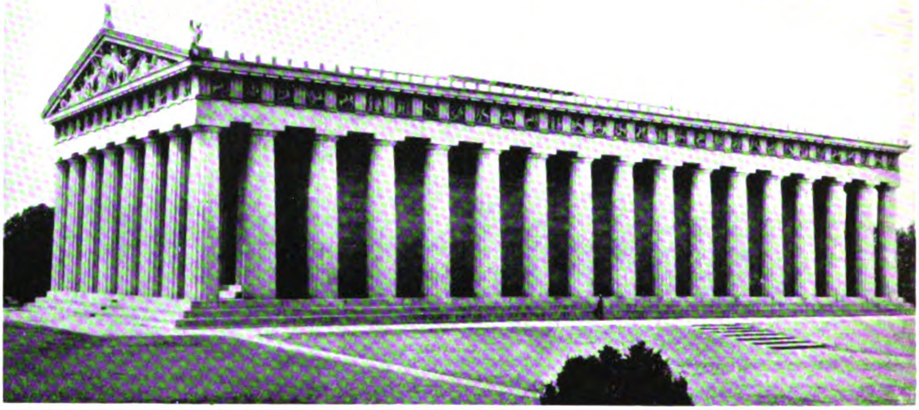
Frontispiece.



THE PARTHENON IN CONCRETE.

This building, an exact reproduction of the Parthenon in reinforced concrete, is the Art Gallery at Nashville, U.S.A. The surfaces have the same tint as the original, and the intricate bas-reliefs are followed in detail.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XXI. No. 1. LONDON, JANUARY, 1926.

TWENTY-FIRST ANNIVERSARY NUMBER.

Progress.

WITH this issue, *Concrete and Constructional Engineering* enters its twenty-first year of publication. The first reinforced concrete structure in this country was built in 1897, but it was not until a few years later that this new method of construction attracted sufficient attention for it to be regarded as a rival of other methods and other materials. This journal has thus been in existence during practically the whole of the history of the industry it serves. Since the first issue those responsible for its conduct have aimed at a consistently high standard, both in its contents and production; they have attracted the leading men in the industry to contribute to its pages, and we still count among our regular contributors the most prominent authorities on the subject.

The prestige this journal has achieved may, we think, be judged from the eminent men in every branch of the industry who have written for, and helped us in producing, this special number, and we take this opportunity of expressing our cordial thanks and appreciation of their kindness. Our object has been to obtain the views of those who have made a special study of all the different aspects, practical and æsthetic, of the uses of concrete, and we are sure their views expressed in this issue will be read with unusual interest. We have also endeavoured to give as complete a history as possible of the progress of the industry during the past twenty-one years. This section, with the illustrations of reinforced concrete structures of every description built in this country, is a striking demonstration of the enormous development of the industry within such a short space of time, in which this journal has played no small part; it shows a virility which can hardly have been equalled by any other industry.

This issue is profusely illustrated, a large proportion of the structures depicted being abroad. This is not because we would have found it impossible to obtain sufficient illustrations of concrete structures of artistic merit in this country, although we should certainly have found it more difficult. An architecture of concrete cannot be produced on a drawing-board at the first attempt; it must be evolved out of what has already been done, learning from both the successes and the failures, and our illustrations have been collected with a view to showing some of the best architectural structures in concrete irrespective of their locality.

In wishing our readers a very happy and prosperous New Year, we take the opportunity of looking a little farther ahead. We wish the industry as great a rate of progress in the next twenty-one years as in the past; then, in 1947, we shall indeed see the fruits of the pioneer efforts recorded in this issue.

EDITORIAL NOTES.

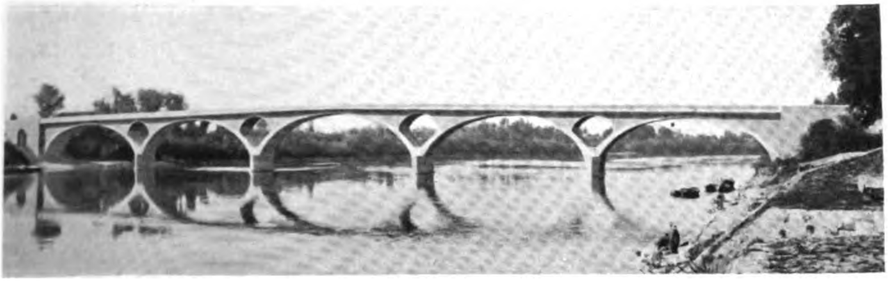
"The Concrete Age." If this issue emphasises one thing above all others, it is the enormous number of reinforced concrete structures already in existence in this country. Even those intimately connected with the industry will, we think, be surprised to see, from the lists of the works of some of the leading firms given under the heading "Progress During a Quarter of a Century," how the country is now covered with reinforced concrete structures of all kinds; and it should be pointed out that, although we have made every endeavour to make this section complete, by no means all the firms who have executed work in reinforced concrete are represented, that the lists sent us are of the most important works only, and that considerations of space have led to many of them being cut down still further. If the "Concrete Age" has not yet arrived, we are certainly a good way towards it.

[Mrs. Phœbe Stabler, A.R.B.S., Sculptor.

"The Young Mother": Carved in Concrete.

Some Early Structures. Those who are accustomed to hear reinforced concrete spoken of as a "new material" will also be surprised to know that even in this country, where this method of building construction was introduced after it had been in existence for some time abroad, reinforced concrete structures were built so long ago as 1897, and that structures built then still survive in as good condition as when built. In this age of progress it is an anomaly still to call reinforced concrete a "new" material; aeroplanes, cinemas, chars-à-bancs and wireless are all later developments which have lost their novelty and are no longer termed "new." We doubt if in any other industry is conservatism so inborn that a method or material would be referred to as new after it had proved its worth over a period of thirty years.

The Future. What of the future? We do not think we can do better than refer to the views of the eminent contributors to this issue. These include architects, engineers, public works contractors, builders, and others whose names are household words in the professions and industries connected with building. All are optimistic in their



Reinforced Concrete Bridge at Tonneins, France.

outlook on the future, and exhibit that enthusiasm without which the industry would never have reached its present importance and status within such a short period of time. Sir Ernest Moir, Bart., has no doubt that we are coming to the "concrete age," and sees no limit to the use of the material. Sir Owen Williams reiterates that concrete is no longer a substitute, and that it has definitely emerged as a reliable structural material. Mr. E. C. Hannen predicts a great future for the material, with the reservation, born of his long experience in the pioneer work of developing improved methods and materials in the industry, that it be not unduly handicapped by restrictive by-laws and regulations. And so on throughout the valuable contributions from these leaders of the industry.

By-Laws and Regulations.

Both Sir Henry Tanner and Mr. E. C. Hannen refer to the hampering effect of most of the existing reinforced concrete regulations, generally framed so long ago as to be entirely out of sympathy with modern building science and practice. It is to be hoped, however, that much of this cause for complaint will disappear when the new London County Council Regulations, now nearing completion, are published and put in force early this year, as they probably will be. We are unable to give any outline of the changes to be effected, but in view of the keen appreciation of American methods displayed by Mr. Topham Forrest, Architect to the London County Council, after his recent visit to the United States, it can be confidently predicted that they will go a long way to meet the wishes of the industry, consistent with the public safety. Mr. A. E. Wynn tells us in this issue that the flat-slab system is almost universally used in America, and it is more than probable that the new regulations will permit this method of design to be adopted in this country.

Building Costs.

Mr. George Burt, of Messrs. John Mowlem & Co., Ltd., gives some interesting figures as to the relative cost of brickwork and concrete in walling, and we sympathise with his plea that concrete be given more consideration by architects concerned in keeping down costs. As he says, "modern architecture 'demands' brickwork, and only occasionally 'permits' concrete," and until all architects get to be more familiar with the material this state of affairs will probably continue. Many architects have already realised the possibilities of concrete, from both the æsthetic and economic points of view, and we are sure that when the many excellent examples of concrete architecture already built and in course of erection become better known we shall see a great impetus given to the more general use of the material by architects.

Design in Concrete.

It is this want of illustration and example, inevitable in the comparatively early days of a new material, that is responsible for much of the lack of progress in the direction of architectural style, as Professor Richardson so well points out. It is one of the difficulties of the architectural schools in that whereas there are available text-books on design in every other material there is none dealing with concrete design. No tradition can be evolved without a full knowledge of what has gone before, and it is largely for this reason that we have selected so many illustrations of foreign works for publication in this issue.

[*Mr. F. W. Doyle Jones, Sculptor.*

Figure personifying the Strength of Concrete.

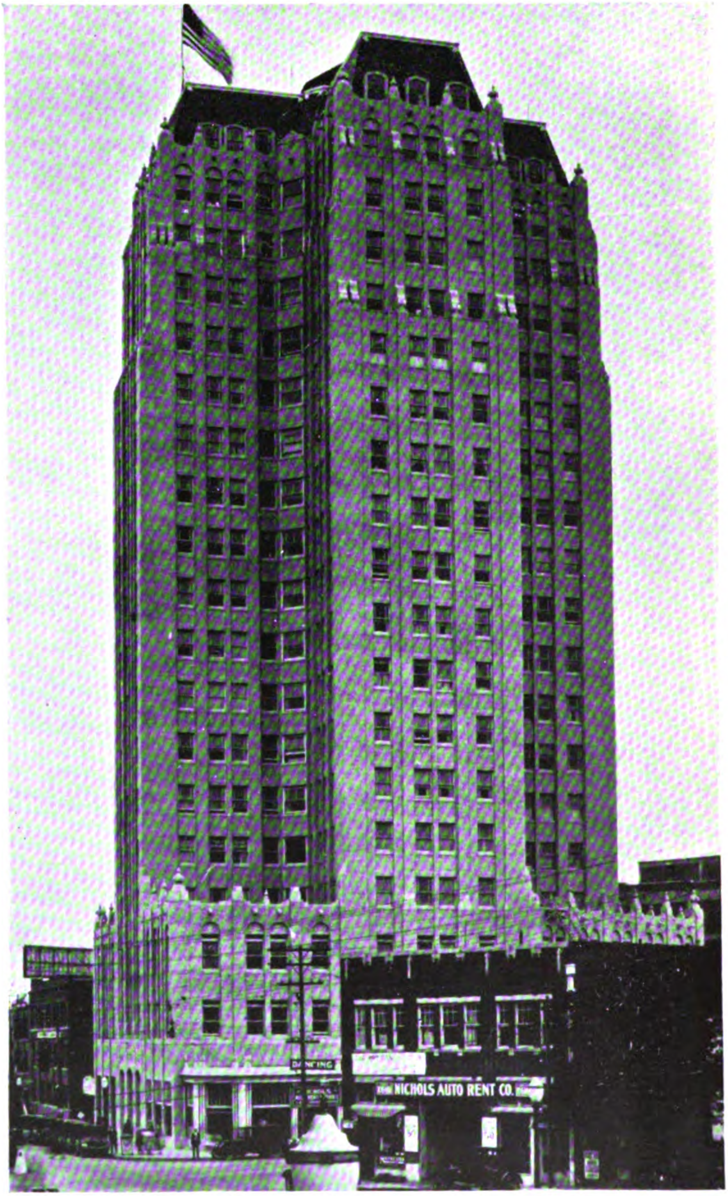
(*Concrete cast in sand mould.*)

A Prize for Reinforced Concrete Design.

THE instructors at the architectural schools are labouring under very great difficulties on account of the lack of illustrations of reinforced concrete buildings with architectural pretensions, but that the subject is not being neglected is shown by the illustrations in this issue of the work of the students at London University School of Architecture, under Professor Richardson and Mr. H. O. Corfiato. Here design in reinforced concrete is part of the training, resulting in many excellent designs, and to encourage this in some small way the Proprietors of *Concrete and Constructional Engineering* have offered an annual prize of £25 for competition amongst the students of London University School of Architecture, and this has been accepted by the Senate. Each year a subject in reinforced concrete will be set, and the designs published in this journal. We think it of the utmost importance that design in reinforced concrete should be encouraged in the architectural schools, and if others concerned with the well-being of the industry would give prizes to other schools we should have a rising generation of young architects with a thorough understanding of the material. We should like to see every architectural school with special prizes to award for design in concrete.

Concrete House in Florida.
(Cement stucco on Concrete blocks.)

Concrete Houses. A THOUGHTFUL contribution by Mr. Arthur Kenyon, F.R.I.B.A., who is Mr. Louis de Soissons' partner in the erection of over 500 concrete houses at Welwyn Garden City, will be read with interest by all concerned with the progress of concrete housing. While obviously enthusiastic in his outlook on the use of the material, Mr. Kenyon realises its limitations, and it is in this direction that his views are particularly valuable. He says : " Let us not be led away with the idea that concrete in its raw sense is beautiful. Far from it. But let us realise its possibilities, and *make* it beautiful." It is in this spirit that we shall get the best results, and Mr. Kenyon and his partner are showing us one way in which this can be done by the cement-colour-washed houses (illustrated in this issue) which are giving an air of brightness and gaiety to a large area of small houses at Welwyn. Mr. Charles Boot, the head of the firm which has built more concrete houses in this country than any other, deals more with the cost and construction of concrete houses, and in conclusion says, " I am quite content to stake my reputation as a building craftsman upon the efficiency and permanence of a properly-conceived system of concrete houses. . . . They will without doubt outlast houses built in any other method." Such a statement is not made unless based on a solid foundation of fact, and is supported by the example quoted of 200 concrete houses built more than fifty years ago which have not cost a penny in maintenance since the day they were built.



Medical Arts Building, Dallas, Texas.

(*Reinforced Concrete Frame ; 19 stories high.*)

Concrete and its Possibilities.

By SIR ERNEST W. MOIR, Bart., M.Inst.C.E., M.A.Soc.C.E.
[*Director, S. Pearson & Son (Contracting Department), Limited; Chairman, Committee on New Methods and Materials for House Construction.*]

THE invention of Portland cement by James Aspdin just over a hundred years ago was undoubtedly an epoch-making achievement, the full significance of which, as so often happens, was not realised for some years.

The essential difference between masonry constructed by the joining of stones by mortar and concrete masonry is the lack of adhesion in the case of the former, which makes it impossible for architects and engineers to apply tension to any part of their structures. This difficulty can be overcome by the use of concrete associated with embedded steel, which makes possible the design of entirely original effects unlike anything the Egyptians, Greeks, or Romans (whose architectural models so generally form the basis of our best work to-day) were able to produce.

Concrete is masonry put in place with a shovel, and when reinforced with steel has the essential difference above described in its power to resist tensile stress.

Concrete in Architecture.

The old builders of Gothic structures in masonry realised the limitations of the material at their disposal, and in ecclesiastical buildings found it necessary to modify the original forms they had in mind. The interiors of mediæval cathedrals invariably give one the same impression as an avenue of trees, the columns branching out into intermingling stone ribs in the vaulted ceilings, and it is probable that this was the effect the old builders strived after. Nature, however, provided for tensile resistance in the tree trunks, which made for stability, and did not call for aisles of buttresses to enable the nave to remain stable and stand without side supports. Trees make up for the lack of buttresses by the resistance of their fabric to tension, both in their spreading roots and in their branches.

All these beauties can now be achieved by the use of ferro-concrete. Had Christopher Wren had such material to deal with the difficulties of the central dome of St. Paul's would not exist. The necessity for the immense

The Largest Viaduct in the World: in Pennsylvania.
(*2,375 ft. long; 240 ft. high; 10 arches of 180-ft. span and 2 of 100-ft. span.*)

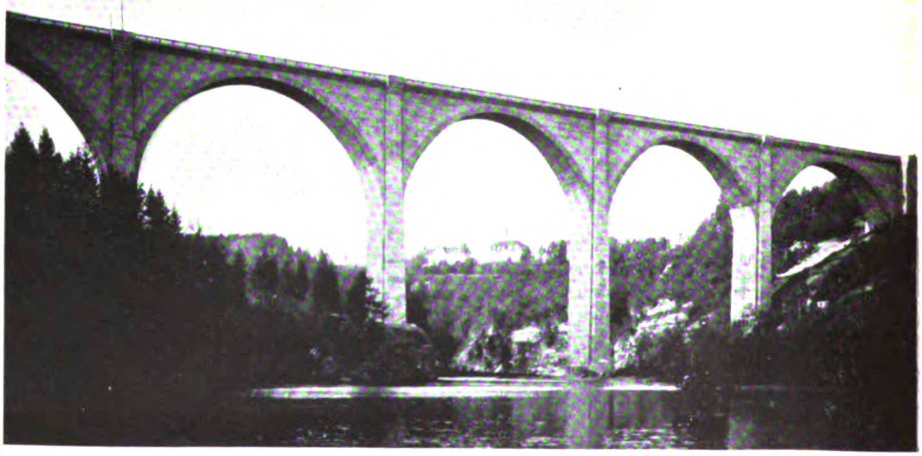
mass in his dome to make it possible to rear it on relatively slender piers required a great vertical load to overcome any possible tension in the supporting columns. Wren's difficulty also of resisting the shear stresses in his masonry and brick brackets, which have not withstood the strain upon them, would have been negligible had he been able to use reinforced concrete. It is possible the replacement of the great brick internal cone by a ferro-concrete one may yet help to the solution of the difficulties at St. Paul's.

It is a pity that architects and the engineers of to-day have not fully realised the beauty and economy that can be produced by the adoption of ferro-concrete with due consideration of the possible tensile resistance provided by its use. No doubt this will come, but it is coming very slowly. One has only to look at some of the Continental and South American designs, frequently seen in racecourse stands, to realise the elegance of structure that can be produced by taking advantage of the tensile strength of ferro-concrete.

Our builders of Gothic cathedrals to-day are few in number; they seem to use concrete with hesitation, and, I fancy, look askance at the use of ferro-concrete. In their designs they rely entirely on transmitting the loads to earth through heavy buttresses, which transmit the stresses at a steep angle to the foundations, the horizontal component of which ultimately passes to the other side of the structure through the tensile resistance of the earth itself. In all old buildings tension in masonry never enters into the possibilities of design. Fortunately the ratio of expansion, under varying temperatures, of steel and concrete is about the same where the structure is of sufficient thickness to cover the steel properly.

Design of Dock Walls and Dams.

Even engineers who should be awake to the possibilities arising out of these facts take little advantage in the design of dock walls and dams of anything but the weight arising from their cross-sections. I have seen structures that do so, though regrettably not in our own country, where the resistance to tension of ferro-concrete has been



Reinforced Concrete Bridge with Arches of 186-ft. Span in Switzerland.

Washington Mills, Massachusetts.
(Reinforced Concrete Frame Building.)

utilised for the purpose of dock wall construction, the necessary weight to keep the dock walls upright being provided by cheap earth or sand filling resting upon a horizontal platform at their bases. The principle used in these designs involves the resistance to tension of ferro-concrete, so that the weight of filling is applied to resist over-turning.

The use of concrete in foundations has been realised for many years. Before the introduction of Portland cement, lime was used for the mortar matrix. The old Roman builders, with their mixtures of finely-ground burnt clay, and burnt limestone disintegrated by hydration, which was described by the generic term of " puzzolana, " came very near to Portland cement.

An Early Example of " Reinforced Concrete."

The earliest instance to my knowledge of the use of what might be called " ferro-masonry "—a combination in this case of iron with brickwork—was the iron bond utilised in the parapets of London Bridge. This was composed of hoop-iron bedded in the mortar, a piece of which was shown to me many years ago by the late Sir Benjamin Baker. It is interesting to record that in the early days of ferro-concrete this great engineer had but little faith in it, but I am sure, had he been alive to-day, his bigness of mind would have allowed his opinions to be modified ; he was, however, primarily a man of steel structures, and the use of high-tension alloys in such.

Advantages of Reinforced Concrete to the Contractor.

I hope I have not departed too far from my text in making the above observations. The Editor said he desired to have something from me about concrete from a contractor's point of view. I can only say generally that the experiences of a contractor are of such a character that any prejudice he may ever have had has long since passed away. He welcomes the ferro-concrete pile and all it means for permanency, and he welcomes the possibility of a material that combats the ravages of the marine insect. The introduction of concrete has given him a chance of improvements in methods of construction, and a means of breaking down old boundaries between the essentially skilled hand labour, and the use of machinery and of labour more or less unskilled.

Spanish Type Bungalow, California.

Economy of Leaner Concretes.

The contractor is sometimes mystified, as must be the cement manufacturer, to realise how many of our engineers have gone on, year in and year out, tightening the requirements of their specifications for cement but taking little interest in utilising the greater strength of the finer material which the cement maker has produced. In many cases one finds modern specifications calling for mixtures of 6 to 1 cement concrete, and not infrequently even 5 to 1, when the cement used is very much better than that produced a few years ago. No real attempt seems to be made to take advantage of the better material placed at his disposal by the enterprising cement manufacturers and cement chemists. Why weaker mixtures should not be used under the circumstances it is difficult to understand.

Grading.

The Thames Valley and its district has been unusually rich in opportunities for the provision of raw material for the structures which can be produced from concrete, reinforced and otherwise. Our Medway mud and chalk gave us a lead in the manufacture and use of cement. Our Thames ballast, generally, is well graded for use in concrete; it is the best of its class and up to recently has been cheap. I submit, however, that the existence of this material—the Thames Valley gravel—has somewhat spoilt our engineers, and venture to suggest that a good deal more

Mrs. Phœbe Stabler, A.R.B.S., Sculptor.

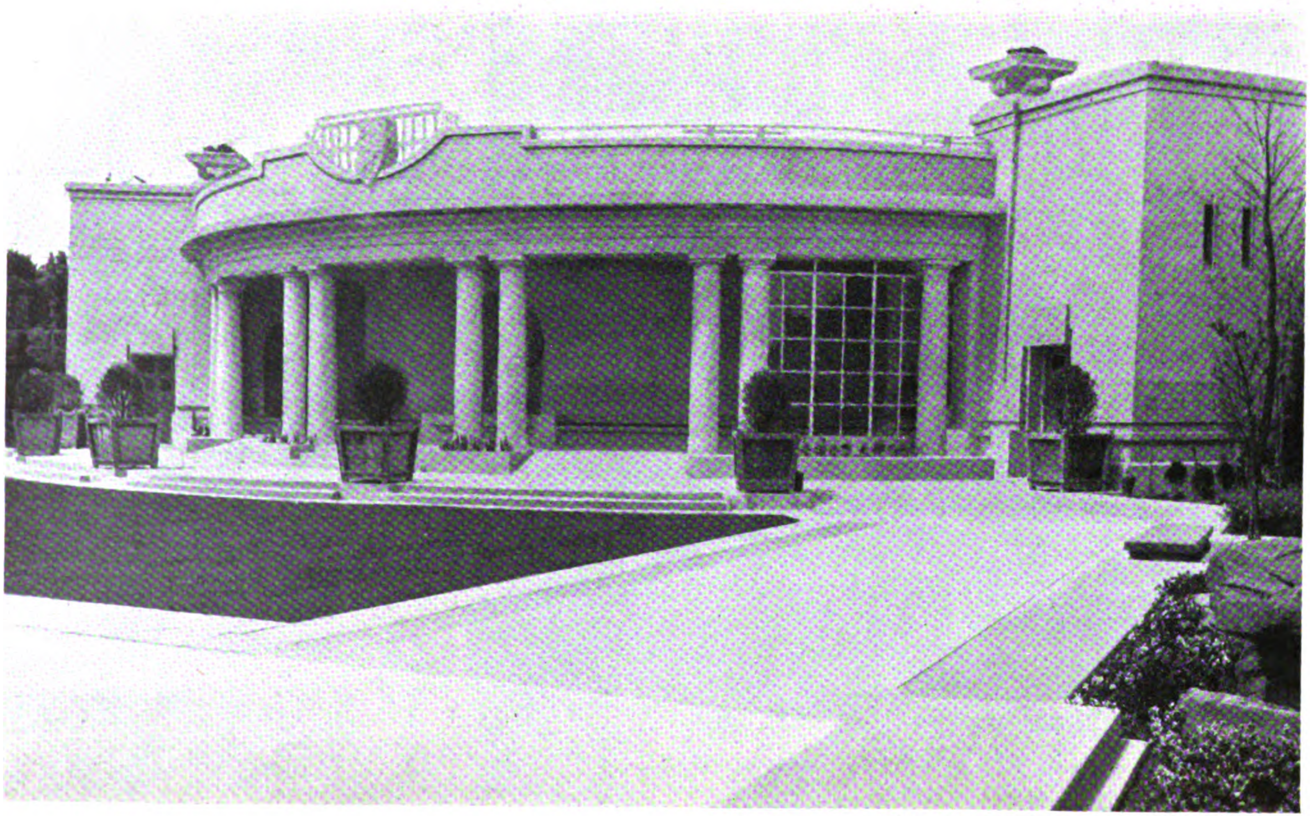
Garden Figure and Bird-Feeder : Carved in Concrete.

science has been put into the specification of concrete ingredients by their Continental brothers and those of America.

Obviously the most dense concrete is that in which the voids are most nearly filled by varying gradations of size in the material commonly called "aggregate." The cement should only have to fill the voids left by the combination of a very large variety in the sizes of particles of the aggregate. I know of a place in Brazil, on the Amazon, where splendid clean, sandy material was available, but it was so uniform in size that its voids were relatively great in the mass, and in order to make large concrete blocks it was essential to allow an exceedingly rich mixture of cement to make a sufficiently strong block for sea-wall building purposes. Had this material been composed of a great variety of sizes a large economy in cement would have been possible with an equally good block, but it had to be taken from a definite place, with the result that far more cement was required than would otherwise have been necessary.

Future Possibilities.

The use of concrete in the future does not seem to have a limit. There is no doubt we are coming to what may be some day known as the "Concrete Age," though we have not arrived there yet. Big possibilities exist in housing, not only in the structure of the walls, but, if we can get an aggregate so light and at the same time free from expansion and contraction due to variations in temperature and moisture in the atmosphere, we shall go a long way towards making our internal fittings—doors and their frames, for example—of concrete instead of wood. Recently there have been discoveries which point to much lighter concrete ingredients, in fact I have seen samples of concrete which float. Houses have been built on the Continent made of light concrete only a few inches thick, which is reported to have been mixed in the ratio of 9 to 1 or 10 to 1. Here, truly, the constructors have taken advantage of the improved manufactures of cement. One is inclined to think in this case they have been a little bold, as some of these buildings are three stories high and subject to the possibilities of high winds; but there is undoubtedly a future for a light concrete, and it is interesting to know that an "aerated" concrete which will float on water is being used for encasing the steel columns of the new Devonshire House in Piccadilly.



[Sir J. J. Burnet & Partners, Architects.

Ramsgate Sea-Front Improvement: A Sun-Shelter in Cast Stone.

(All in Cast Stone.)

Concrete: Its Present Handicaps and its Future Possibilities.

By SIR HENRY TANNER, C.B., I.S.O., F.R.I.B.A., F.S.I.

(Late Chief Architect to H.M. Office of Works.)

It has been suggested to me that I should state my views and opinions in regard to the future of reinforced concrete construction and its design.

By-Laws and Regulations.

Concrete construction is governed in this and most countries by by-laws or regulations, the character of which may be more or less strict, but which leave little latitude to the designer; neither does there seem to be any endeavour to take advantage of the improved quality and strength of modern Portland cement. In proof of this the requirements of the London Building Acts in the case of cement mortar remain as they were seventy years ago. Having regard to the quality of the cement of the present day it would seem that the time has arrived for this and other requirements of the Acts in which the use of cement is governed to be brought up to date. In the works carried out under my directions, and exempt from the control of these Acts, the proportion for mortar for the last twenty years has been one of cement to six of aggregate, and I believe that this continues to be the rule in H.M. Office of Works.

The same criticism applies in the case of reinforced concrete except that the Regulations which were drawn up by the London County Council were only issued in 1915. They were largely based on the Report of a Joint Committee published in 1907 and revised in 1911. Nearly twenty years have elapsed since the report of the Committee was first issued, and even during this period the quality of cement has vastly improved and demands a reconsideration of the existing regulations.

The Superintending Architect to the London County Council, however, in his report on his visit to America, does not seem to foreshadow any revision due to improvements in the quality of the cement, the reason being his fear of the excessive amount of water frequently

[*M. Roux-Spitz, Architect.*

School of Metallurgy, Lyons.

used; but this should be provided for, as it is not general.

The London Regulations are frequently adopted elsewhere as a model, and thus their disadvantages are extended to other parts of the country.

Speed of Construction.

Another difficulty affecting the development of reinforced concrete construction arises from the slow progress generally made with buildings. Whether there can be any advance in this aspect of the question is mainly one in connection with the construction of the shuttering, which as now practised is usually a lengthy and wasteful business. Where there is frequent repetition, and this is generally the case, much might be done so to construct the forms that they could be made adaptable, have a much longer life, and at the same time facilitate and expedite the erection of buildings as well as reduce the cost owing to the price of timber and the waste which generally takes place.

Work might also be speeded up if slow-setting and rapid-hardening Portland cement were more generally used, so as to enable the shuttering to be removed in a much shorter time than is the case with the ordinary cements. The use of such cement is not, however, contemplated in the Regulations, although contractors will more readily use rapid-hardening cement when they realise that the earlier removal of the shuttering which it makes possible will more than compensate for the slight additional cost of the material.

Reinforced concrete building has not, in my opinion, advanced at anything like the rate that might have been anticipated, any advance which has taken place being chiefly in connection with municipal and engineering works.

At the present time, perhaps more than ever, expedition is necessary; time is the equivalent of money, and unless greater efforts are made to speed up this form of construction for building works prospective owners might prefer to adopt steel or other forms of construction, at some increase in cost, if possession of the completed structures could be obtained at an earlier date. It should be borne in mind that steelwork can be progressing from the very commencement of the work, and erection may be very rapid.

The Superintending Architect of the L.C.C. recommends that superloads should be considerably reduced, which is all to the good. It is also recommended that the stress in steel be increased to 8 tons, but this stress might be quite safely further increased for all ordinary buildings.

Problems of Design.

The use of reinforced concrete might well be extended in many ways, and in these notes I have endeavoured to draw attention to those points which require modification or improvement to enable this to be done.

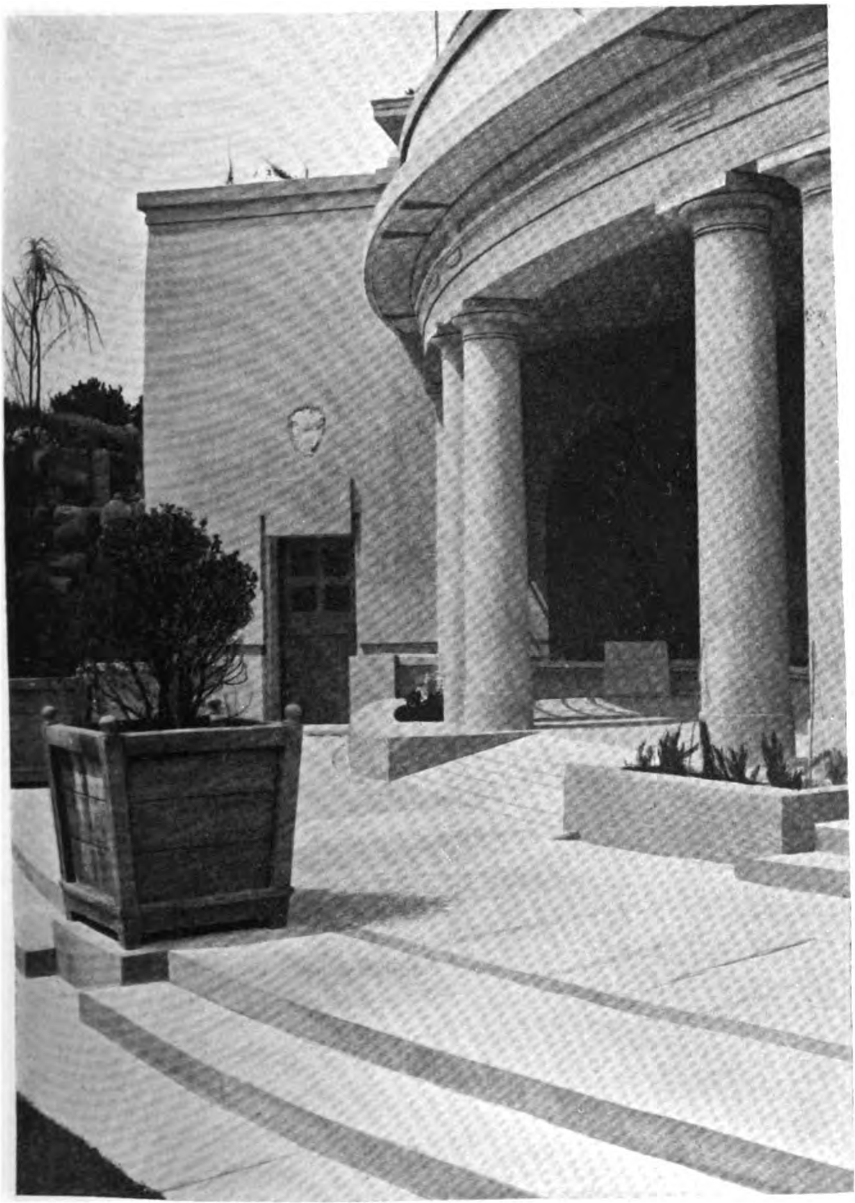
With an increasing use of concrete construction it is certain that design will improve and develop. What may be done with it on a large scale has been well shown at Wembley, and it is difficult to see how anything like the effects produced there could have been obtained in any other way having regard to the necessity for economy when the buildings were required more or less for temporary use.

Many satisfactory factory buildings have been erected, generally of simple straight forms, the use of curves and mouldings being avoided as far as possible. So far, however, reinforced concrete buildings in streets have been few, and then the reinforced concrete structure has simply taken the place of a steel-frame structure and has been clothed in a similar manner. If there could be an added inducement to adopt this form of construction an increasing number of architects would join in the efforts to produce designs suitable for the material, which is capable of considerable variety in regard to colour, texture, and general surface treatment.

Satisfactory Progress.

Reinforced concrete construction is only about a quarter of a century old in this country, and when this is considered and that *Concrete and Constructional Engineering* is only just "of age," the progress made cannot be regarded as altogether unsatisfactory, especially when one reads of the length of time that it took to get people accustomed to the use of reinforced concrete at all.

The building world has much to thank the late Edwin O. Sachs for, as he not only helped to found the Concrete Institute, which has now changed its title to the



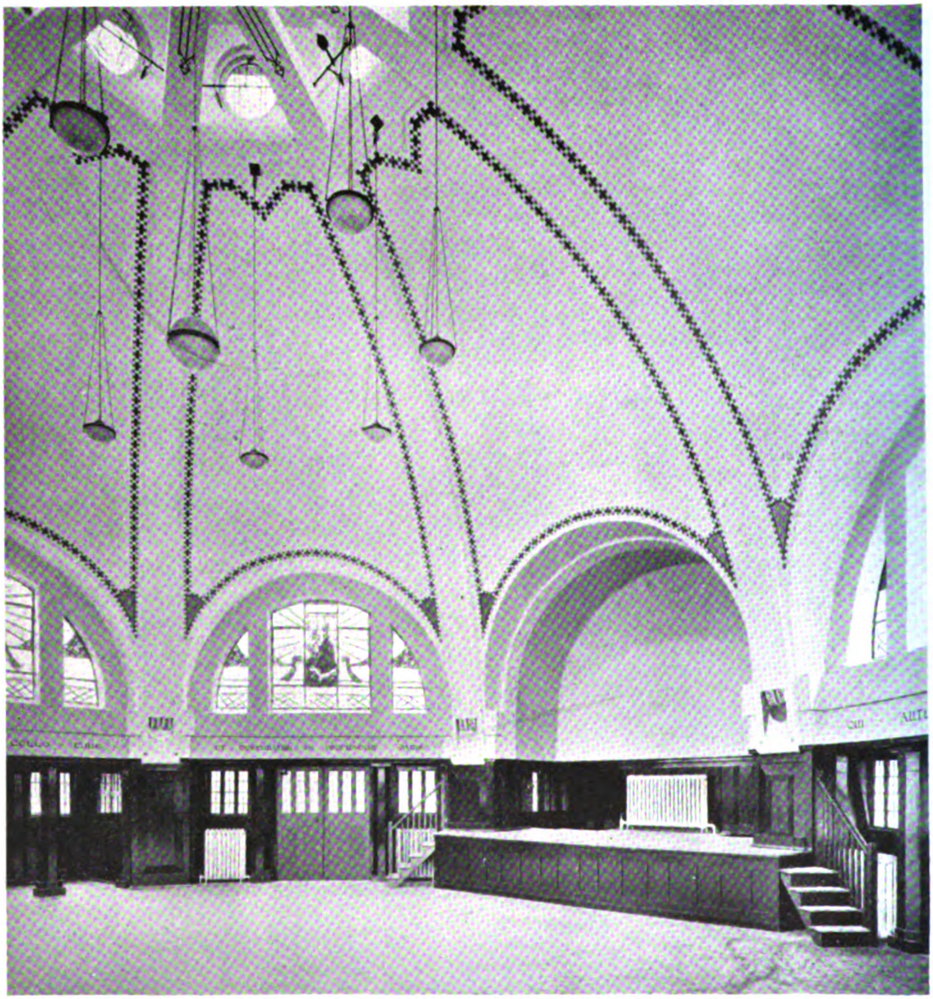
[Sir J. J. Burnet & Partners, Architects.

Ramsgate Sea-Front Improvement.

(All in Cast Stone.)

Institution of Structural Engineers, but, I believe, also this Journal and the British Fire Prevention Committee. There is no doubt that his efforts did much to make known and to increase the popularity of this method of construction, while the experiments conducted by the Committee demonstrated the power of concrete to resist fire and to show which aggregates were likely to give the most satisfactory results from this point of view.

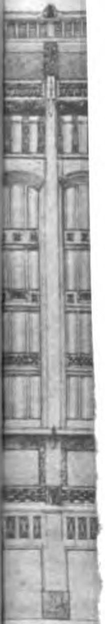
In conclusion, I wish continued usefulness and prosperity to the Journal.



[*Mr. G. H. Widdows, F.R.I.B.A., Architect.*

Interior of Dome at Ilkeston.

(*Design Stencilled on Concrete.*)



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UNIV. OF MICH.

Towards Simplicity.

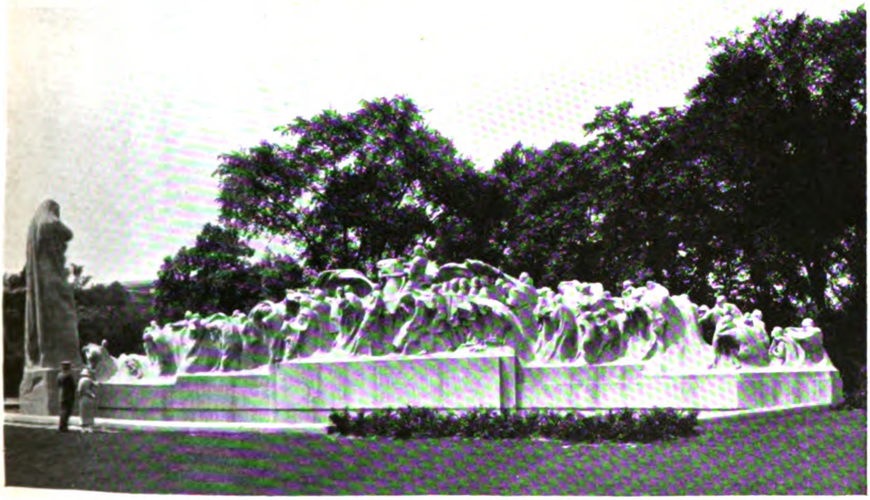
By **SIR E. OWEN WILLIAMS, K.B.E., B.Sc., M.Inst.C.E.**

THE concrete industry may look back on the past twenty-one years with pride in its achievement. Concrete has definitely emerged as a reliable structural material. It is no longer a substitute; its own definite and peculiar qualities demand its use. Now "all men speak well of it," and herein lies its danger. Looking backwards may be a source of pride and elation, but a contemplation of the past, except as a guidance for the future, is futility.

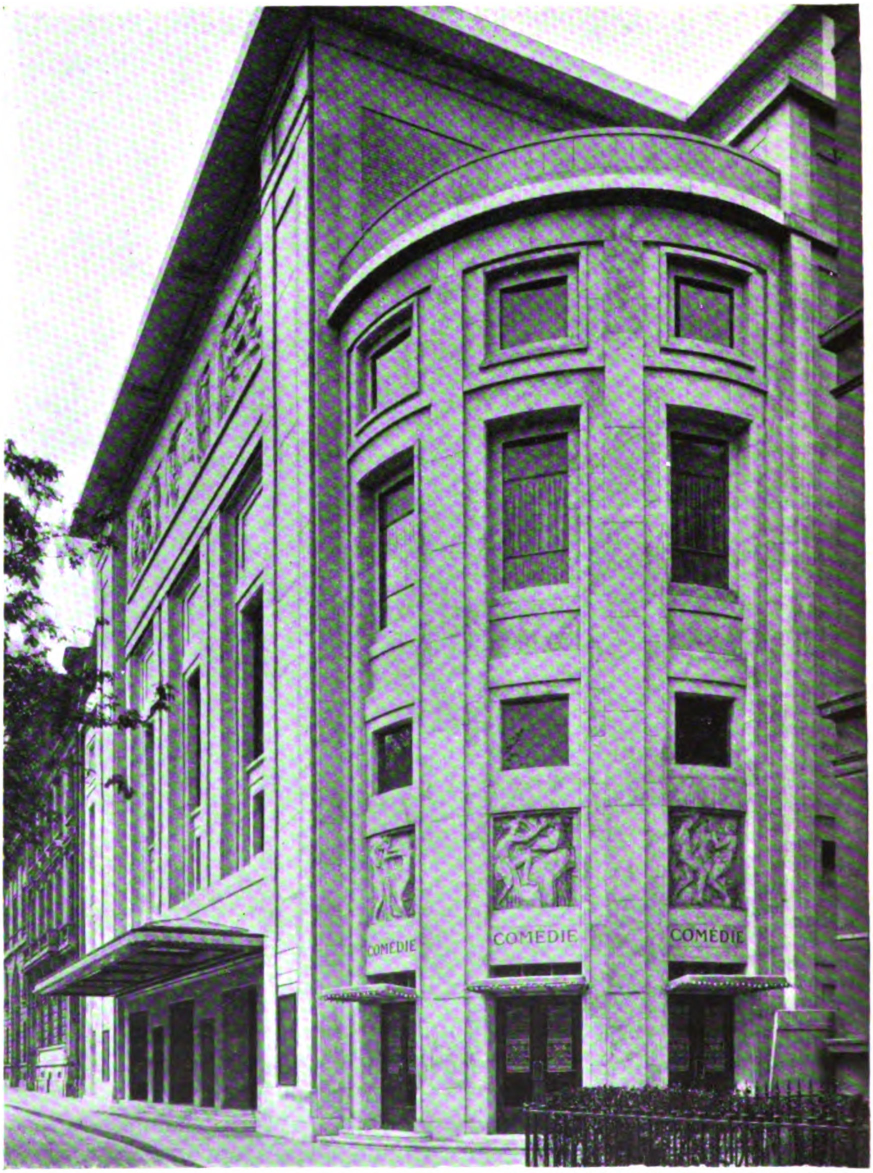
The speedy development of concrete has brought in its trail complications in design and construction which ages of use have eliminated in older materials. It is not to be expected that the minds of men can assimilate rapidly as well as simply the essential properties of a new material. The properties at first are very elusive; one theory succeeds another, leaving the mind bewildered but still having to carry on with the use of the material. A simple, direct, even unmathematical, outlook on concrete and reinforced concrete will alone shape the material into its own peculiar forms, instead of imitating the forms which other materials have developed for themselves.

It has often been said that more money is lost by contractors in "muck-shifting" than in any other branch of contracting, because of the very simplicity of the operation not being regarded in a simple manner. The same may be said of concrete. It is the most simple of materials, and because of this simplicity a complex attitude of mind towards it will delay, even if it cannot prevent, its complete development.

The growth of concrete and reinforced concrete in the next twenty-one years would be phenomenal if all engaged in the industry took as their guiding principle "*Simplicity.*"



The "Fountain of Time," Chicago.
(*Statuary Group in Poured Concrete.*)



[MM. A. and G. Perrett, Architects.

Champs Elysées Theatre, Paris.

(*Reinforced Concrete with Marble Facing.*)

Architecture and Structures of Concrete.

By PROFESSOR BERESFORD PITE, M.A., F.R.I.B.A.

WHAT is the architect's point of view? What relation does the design of a building, in the materials and methods of concrete, bear to his ideals of architectural beauty? How can he bring to bear upon this somewhat novel problem his educational equipment, both in the art and science of architecture? Does concrete suggest a new vision of constructed forms, and can it appropriately and reasonably employ the stock of forms and ornaments with which he has been accustomed to clothe his designs?

Questions like these present themselves to the professional mind and should be thought out until answered; but there will remain larger questions that possess both urgency and insistence. Has not building in concrete already assumed a character of its own apart from the aid or leadership of what may be called the School of Architects? And is not this character architectural?

Architects' minds seem usually to fall into two groups, the artistic and the constructive. This division is perhaps natural, but it ought not to be tolerated as inevitable or incurable. The constructionally-minded architect should learn to think artistically, and to this end needs not only instruction but humility, for misguided efforts have disastrously permanent results; and the artistically-minded, more obviously, requires the logic of scientific construction and the patience and honesty of idea that will avoid uneconomical absurdities in design.

The furniture of the artistic mind consists usually of selected types of bygone architectures; it is antique, and supplied by copies, museums and publications which are conveniently described as "examples." The law and testimony of the past govern the soul of the modern artistic architect; his furniture is at once his food and his idol.

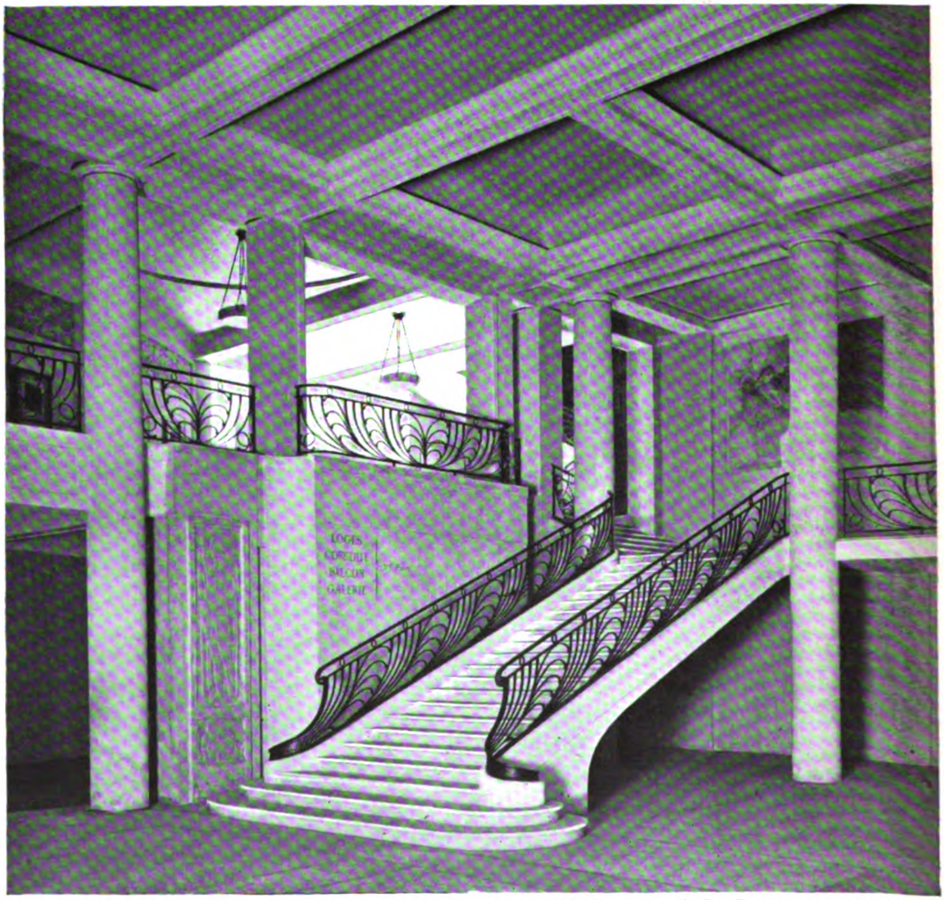
The constructive spirit is unhampered at the outset by tradition; mechanics is a living thing; it pursues a progressive course that seldom turns back. The course may prove to be circular, and history all the while repeating itself, but the movement is always inquisitive of new possibilities and willingly deserts stationary types of design. It scarcely waits to ask if the results of its efforts are architectural, for artistic considerations do not really count. Steel construction for wood, reinforced concrete for brickwork or masonry, plate glass (a bugbear to the artistic mind) for broken-up glazing, and Portland cement for colour and texture, are materials which oust antiquity from architecture.

These opposite frames of mind, however, do not disdain to affect each other's habit. It is part of the necessity of the hour that the architect should be at once an artist and a constructor, so the one constructs his decoration and the other decorates his construction. Architecture being both an art and a science, a combination must be made apparent in creating a building which can be accepted as a work of architecture.

It would seem that the advent of ferro-concrete building must dissolve the odd partnership between past and present. It has neither tradition nor a new stock of ready-made examples of ornament, and the ascendance of the constructor thus becomes complete. If the population of the earth were entirely Philistine the disappearance of architecture could be associated with the discovery of a revolutionary method of building, but, being as we are, the artistic intelligence of the race is bound to exercise itself upon its works, and it cannot be predicated that it ceases to operate where there are neither precedents or stimulants to provoke emulation. An artistic solution is demanded in concrete buildings by the instinct of mankind, and to this task the architect must bend his mind.

Before passing to the means by which the desire for an expressive or particular architecture in concrete may be produced it may be noted that there are elements, fundamental to architectural success in design, which are not greatly affected by the material or system of construction. The frankest Philistine or the solely practically-minded will admit a beauty in the successful convenience and economy of a plan which may often rise to architectural dignity in buildings of large size. The faculty of discerning the susceptibility of requirements to an orderly result is of more value to the architect's client than a purely artistic gift, and it is in the exercise of this valuable service that the training and experience of good architects bear fruit. A considerable advance towards an architectural achievement can be made by the solution of the peculiar object of the building, it may be only by rearrangement of the parts, if the result indicates careful thought rather than a merely rough expediency.

The arrangement of the masses of a plan in vertical elevations follows naturally and brings a new array of problems into view. The heights of buildings minister to the eye more immediately and rapidly than the extent or scheme of a ground plan. The relation of the dimensions of height to practical end rules the effect as much as those of the plan; they play upon each other and create the indefinable result of proportion —it might be said unconsciously—and their total makes a group to be estimated from every point, in front, back, or side view and in perspective. It is unnecessary to invoke the Philistine to tell us that all this must be left to chance or that thought and skill are wasted upon the external appearance of a mass of reckless building. The addition of the qualities of architectural thought to all the elevations will justify itself without raising any question of what is known as "treatment" or ornament.



[*MM. A. and G. Perrett, Architects.*

Champs Elysées Theatre, Paris.

(*Reinforced Concrete with Marble Facing.*)

These fundamental qualities of successful architectural design are common to buildings in any material, whether the granite of the pyramids or the metal plate of a gas-tank; perhaps unconsciously exercised in these examples, they are elements which cannot be either unseen or overlooked. Concrete building, whatever its radical differences in thickness of wall or disposition of pier may be, is subject to these primary architectural elements.

The question underlying the subject of architecture in concrete structures becomes apparent when the disposition of the plan and the relative heights have been settled. It is this. Should the original nakedness of the forms be clothed with some garment of traditional architecture, or should the skeleton of the anatomy of structure be more or less really exposed?

The garment of tradition has had many fashions; the first uses of its several features have become obscure; useful and once necessary parts have become merely superfluous details; and decorations which had sacred intention have degenerated into vain and meaningless ornaments. But the architectural mind of to-day does not affect to be over-serious or critical any more than the world of fashion. Face value is mostly demanded of the designer, as little compunction is felt about the degrading process of disinterring the dead and putting their remains to unorthodox uses. Have not the sacred symbols of Egyptian religion, created in perpetual granite, become the tricks of a style-monger in plaster? Has not the "Corinthian" order been prescribed for the portico of a Christian tabernacle?

Discussion of the illogical and absurd use by moderns of ancient traditional forms in architecture might be indulged at length; it is a subject that distends itself over the whole field of the various renaissances that live upon dead arts. But its elucidation might clear the air for the consideration of an architecture of concrete which the ancient world never knew. Though there is some underlying necessity of clothing in all the vagaries of costume, the discussion must be suspended with the reflection that garments of granite, marble, stone, or wood will probably prove to be misfitting on the plastic mould of ferro-concrete.

The alternative suggestion, savouring of anatomy, of the revealed skeleton, perhaps with a desiccated integument, would have commended itself to the past generation which bestowed upon the architectural association its motto "Design with beauty; build in truth," without defining its terms; a task which may be commended to the thoughtful students of its popular school to-day. Does the prescription for an architecture of concrete lie within this cryptic oracle? Will the expression of extended girders and attenuated supports satisfy the instinct that craves for beauty in building? The system of construction must be admitted. Can its inevitable results, in proportions which, judged by the canons of all other building materials, are abnormal, be harmonised with ideals which are the fruit of very different growths?

It would seem that the concrete builder has in this alternative also to clear the architectural air and think for himself. Does he hold in his hands anything of grace and value in his material that will fructify through inherent qualities into that architectural beauty which the civilised instinct of the community demands? If the answer is to be negative, concrete structures are doomed to the Gibeonitish service of waterworks and dust destructors and such-like, and forbidden to compete with the historic methods of building for the nobler purposes of architecture.

The solution of the problem must lie beyond the superficial consideration that has hitherto been given to the relation of architecture to material. A crowning evil to modern architectural studies is the haste with which students are driven down the fences, terminating in the delusive pitfall of a qualifying examination. This limits and terminates the student life; there is no room for serious investigation of the motives of the builders whose forms are to be absorbed, undigested and misunderstood. The constructive mind has to be furnished of necessity with data and results and taught their application, covering the whole range of materials, among which the science of ferro-concrete must take an increased share. The artistic mind has no proper training at all in the synthesis of material and architectural development.

The evolution of art in building has many aspects, among others, religious, social, historical, economical; but in each manifestation, however much these factors may interplay, the whole result is controlled by and expressed in materials and construction. The causes and effects do not lie upon the surface, and are not to be picked up, copied and exhibited in "testimonies of study" or in frisky designs. There can be little hope of an architecture of concrete structures until architecture is studied as a structural art in the *concrete.*

Memorial Bridge at Fairmount, Virginia.

(*Three spans of* 250 *ft. each.*)

The mind of humanity expressing itself in building; architecture as a form of intellectual expression; the limits of possibility in material, are suggestive themes for students that are not merely titles for prize essays, but lines of direct and fruitful study. The long gestation of Egyptian granite architecture; the mysterious sacredness of Greek types; the sudden immensity of the Pantheon at Rome; the purely practical constructive achievement of Santa Sophia; the northern vigour of the mediæval vault; have each some inner life which must be closely akin to that secret for which we are searching in the new material that now dominates the building world. The architect of a concrete structure must realise that, though the superficial forms are what seem to matter, there is something more in the world's inheritance of building than can be understood by learning styles a dressing up designs with their imit tions.

The use of ferro-concrete for buildin which the Philistine delights to thir are beyond the range of architecture, deems in the meanwhile unworthy monumental uses; a mere constructi expedient to be masked in needless ga ments of stone or brick, hiding its forc and dissembling its value, will invol repression of adventure and experime and delay the advent of concrete as material having the proper dignity t which its permanence entitles it. This generation of architects is stiffnecked in its devotion to a system of education which has been successful in standardising study, but which seems also to have eliminated the energy which once fought a battle of the styles, and built the Palace at Westminster and the Royal Courts of Justice, in defiance of European tradition. We shall not do the like of this over again without the sincerity and zeal of some conviction of failure hitherto and the aspiration of a new ideal.

May it be that the possibility of an architecture of concrete structure will provide this stimulus, and begin at the root by exhibiting the inadequacy of modern architectural studies to deal with this urgent and present problem?

Concrete in Architecture.

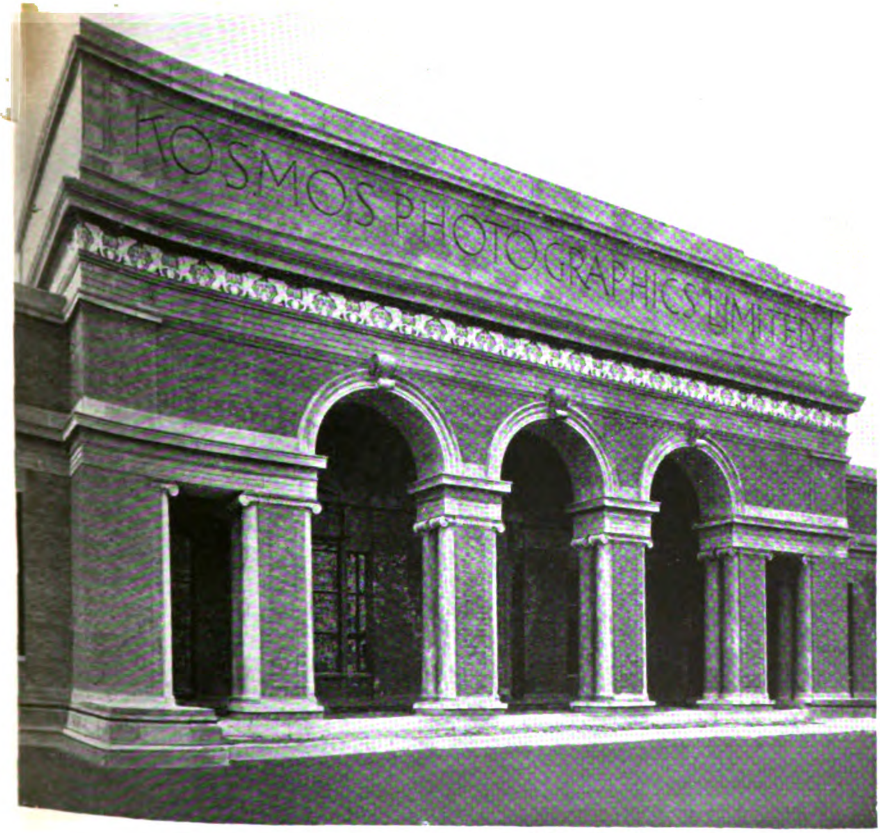
By MAXWELL AYRTON, F.R.I.B.A.

HE growth of all commercial undertak- gs during the past hundred years has rought with it an ever-increasing demand r larger and more spacious buildings nd the elimination of all unnecessary bstructions within them. Much of the nergy and inventiveness of our engineers as been given to this end, and among he fruits of their labours one of the ore important is the science of reinforced oncrete; and being a science based pon necessity it carries with it a force hat must be irresistible.

Design and Construction.

Gradually but surely architectural design is becoming more closely connected with the skeleton of the body it clothes. The effort to hide modern construction behind a screen that apes the work of the previous generations is happily weakening, while the appreciation of straightforward efficiency grows daily.

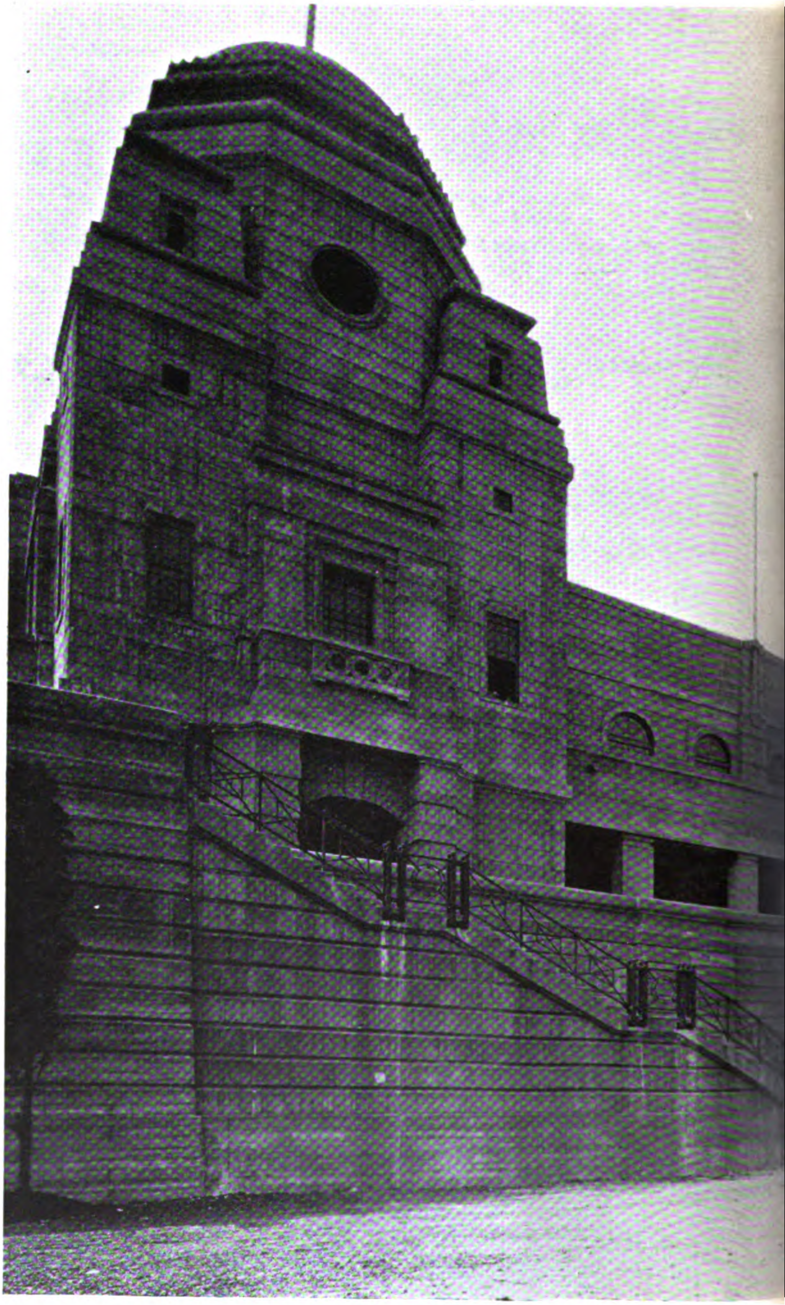
It is to the great commercial undertakings that one should look for the architecture of the day, for if the undertaking, whatever its nature, is to be



[*Mr. T. H. F. Burditt, Architect.*

Factory Building at Baldock, Herts : Central Feature.
(*Built of plum-coloured concrete bricks with pre-cast concrete columns, dressings, and decorations.*)

MAXWELL AYRTON.



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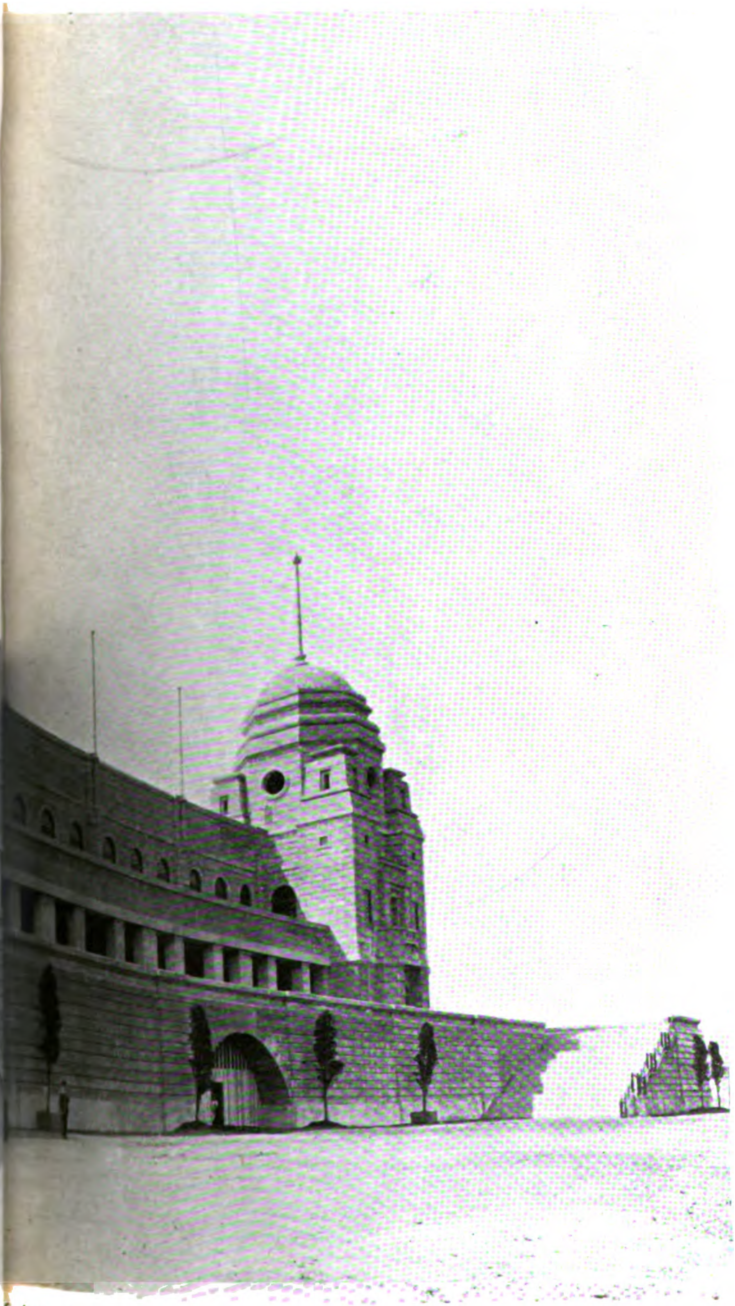
BRITISH EMPIRE



Ayrton, FF.R.I.B.A., *Architects; Sir E. Owen Williams, M.Inst.C.E., Engineer.*

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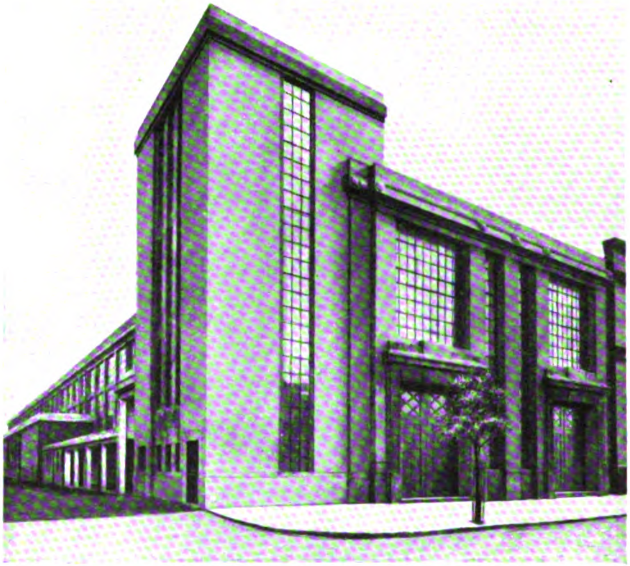


[*Mr. Thomas Wallis, F.R.I.B.A., Architect.*

Building for General Electric Co., Ltd., Witton.

wholly successful it must surely be properly housed.

Perhaps there is no more striking change in the past few years than in the "skyscrapers" of America. Their mere bulk has always been impressive, but how infinitely more so are those of the latter day, in their plain square starkness—where all useless garnishings have been omitted and reliance has been placed solely upon the mass and fenestration?

This is obviously the outcome of the square steel skeleton, common sense having determined that overhanging balconies and whatnots only added to the cost and difficulties of construction and consequently could have no place in a building which above all must be efficient. Internal arrangements and finishings have been affected in a like manner, and here again may be found the desire to abandon all that is unnecessary and to produce buildings capable of upkeep with the minimum labour. Architecture cannot suffer from such a trend of thought—it must inevitably gain, for beauty must be included in perfect efficiency.

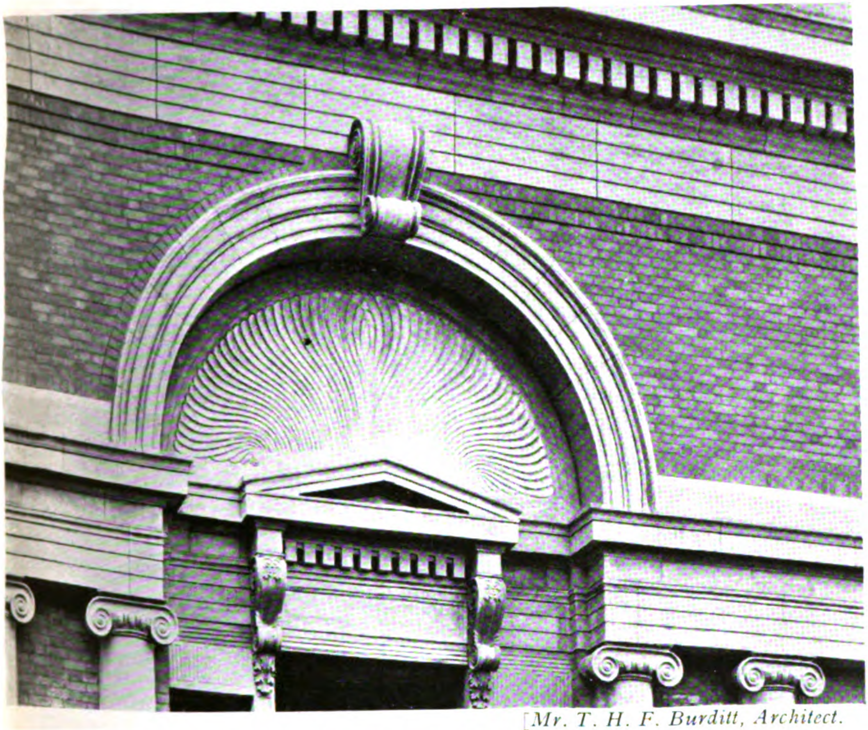
Truth in Architecture.

Reinforced concrete meets these requirements, and it only remains to treat it properly and with the respect due to concrete as a material, when economy must eventually give it the lead over other materials. It is not surprising to find how quickly this is coming about. Experience is rapidly developing ways and means of dealing with concrete as a material worthy of the finest façades, and it cannot be long before it "comes into its own."

Where reinforced concrete is adopted there can only be one reason for adding to the cost by clothing it with a facing of other material, that of hiding something objectionable by something of beauty. And here lies a great danger, for too often it leads to the use of stone, marble, brick, or other material, in forms and positions impossible to them in their proper use. But it is not on this account that the treatment of concrete is receiving so much attention, but upon the finer and only true foundation—that of economy.

Some Architectural Fallacies.

Recent correspondence in *The Times* upon Modernity in Architecture and Architecture in Concrete showed instances of common errors in considering concrete as a material to be used or not used upon its own merits. In an excellent article upon "Modernity in Art," concrete was



[Mr. T. H. F. Burditt, Architect.

Detail of Pre-cast Concrete Work at Factory at Baldock, Herts.

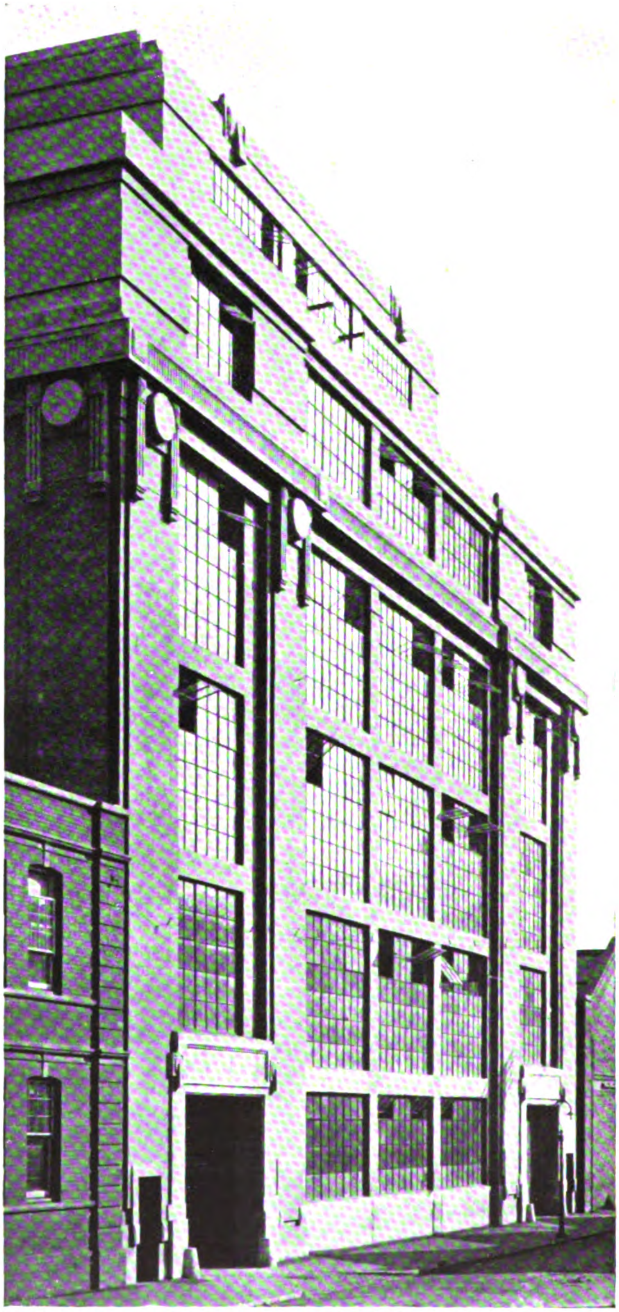
heralded as having boundless possibilities in artistic development "when it is realised that modern science has given the architect a material as plastic as clay itself." In reply to this the writer of the article was accused of confusion of thought upon the vital question of design in reinforced concrete, finally stating that "Far from being released by the new material to roam fancy-free among new forms, the architect is strictly conditioned by the carpenter's skill. And when all is done, the structural expression will be a timber expression."

Both were wrong—the first because concrete cannot be economically used in "fancy-free" forms, and the second in stating that concrete is "strictly conditioned by the carpenter's skill."

Design in concrete is limited by the material itself, that is by the amount of steel reinforcement, the size of the aggregate, and the insurance that the forms are designed in such a manner as to allow the liquid concrete to flow easily and without interruption and are subsequently removable without damage to the concrete. It is in this direction that designers in concrete must turn their attention, as well as to the all-important matter of colour and finished surface.

Surface Finish.

Much good work is being done throughout the country, and there are indications that it will not be long before it is possible to obtain a perfect finish, giving the full value and beauty of the aggregate and cement, direct from the forms and shuttering without further labour. Only when this goal has been reached shall we see concrete recognised by the public as a worthy material for our great buildings.



[*Messrs. Gilbert Wallis & Partners, Architects.*

Tilling-Stevens Factory, Maidstone.

(*In reinforced concrete with exposed concrete surface.*)

Concrete Houses from the Architect's Point of View.

By ARTHUR W. KENYON, F.R.I.B.A.

For generations past there has been little variation in the materials employed in house construction, and people have become accustomed to consider brick and stone as the natural material to be used for walling. Generations of tradition accustomed the craftsman to specialise in these materials; they naturally became very skilled in the use of them, and as there was no lack of material available there appeared to be no object in departing from the methods of past ages.

As times changed, and as a greater number of houses were required in excess of the material and skilled labour available, it was necessary to consider some new type of construction which would enable houses to be built of material other than brick and stone, and also in such a way that labour could be enlisted to a greater extent from the ranks of the unemployed.

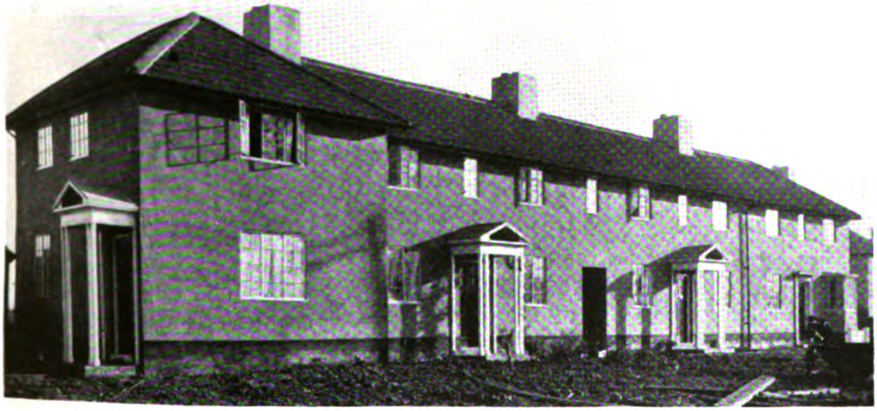
Concrete houses fulfil these conditions, and provided a suitable aggregate can be obtained near the site there is no reason whatever why they should not be built in ever-increasing numbers.

Design.

I feel that concrete houses should not be designed to look like brick with a cement dressing, but should be designed to express the material that is being used. It is not, however, simple to carry out this in a new material without thoroughly understanding its possibilities.

As Mr. Louis de Soissons and I found in designing the first houses in concrete built at Welwyn Garden City, our tendency was to use concrete for walling in place of brick and to face over with cement; we used wooden porches, wooden door surrounds and hoods, wooden eaves and facias, our chimney-stacks were constructed from ground to pots in brickwork. But as we gradually became more familiar with the extraordinary possibilities of concrete we found it was practicable to use it much more generally to supersede other material.

Chimney-breasts and chimney-stacks can be constructed in concrete as easily as in brickwork. We are now designing



[*Messrs. Louis de Soissons & Arthur Kenyon, FF.R.I.B.A., Architects.*

Concrete Cottages at Welwyn Garden City.

our porches in reinforced concrete. We are cutting out the wooden eaves and using concrete slabs, and I venture to think that before the 550 houses which are now in course of erection at Welwyn Garden City are completed we shall have found many more uses to which concrete can be put in house building.

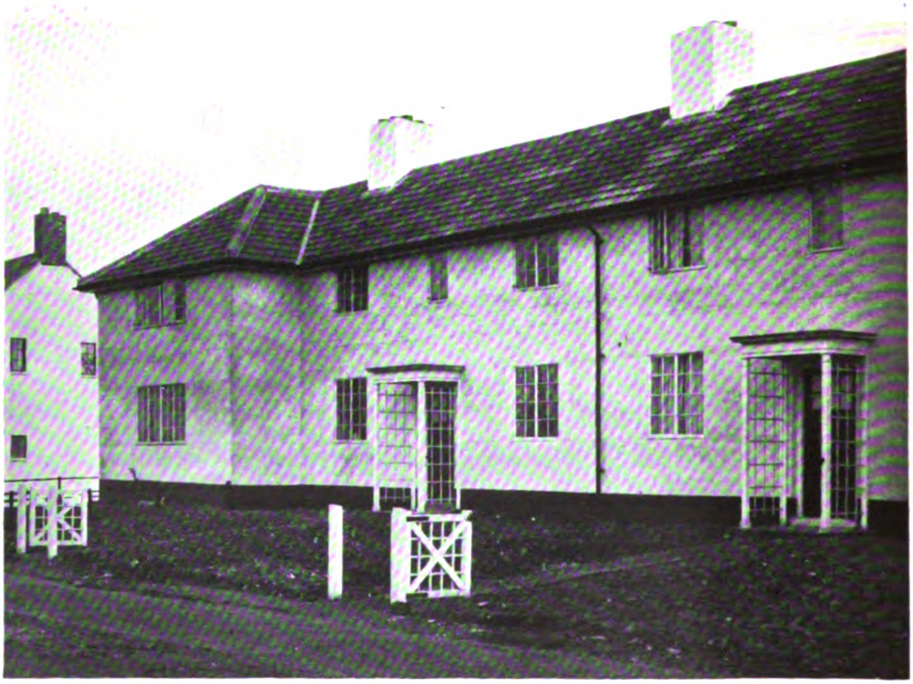
We are at present using concrete tiles, and while I cannot say that æsthetically these compare with clay tiles there is no reason why they should not. We are hoping that the tile manufacturers will study this and explore the possibilities of other types of tiles, and produce something that will give that charm which is so pleasing with the red tile.

Interior Finish.

The question of inside finish to the walls has not yet been solved, and yet I feel that it should be possible so to finish the inside of houses with a smooth surface of concrete walling as to obviate the use of plastering. Condensation is, however, one of the chief difficulties, and some absorbent form of concrete finish would be necessary before this could be achieved. It has been difficult to find an economical and satisfactory concrete floor which will fulfil the good properties of the present wooden floor and at the same time be as reasonable in price, and here again there is scope for ingenuity if the all-concrete house is to be procured.

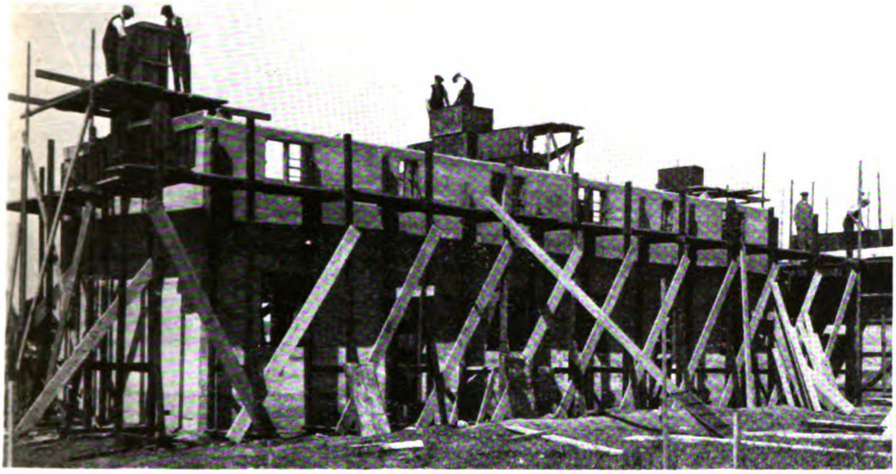
Growing Popularity.

I feel that the concrete house has enormous possibilities. There is prejudice to be broken down. We hear people say they do not like the concrete house, and perhaps this is because it is something to which they have not become accustomed, but when they become aware of their extreme durability, their stability and weatherproof qualities, prejudices will fade away. When they appreciate that concrete houses can be designed as tastefully as houses in any other material they will begin to realise the enormous advantages of this material. The early concrete houses left much to be



[Messrs. Louis de Soissons & Arthur Kenyon, FF.R.I.B.A., Architects.

Concrete Cottages at Welwyn Garden City.



[Messrs. Louis de Soissons & Arthur Kenyon, FF.R.I.B.A., Architects.

Concrete Cottages at Welwyn Garden City: during Construction.

desired in the way of design, but this was no doubt due to the lack of study put into these first efforts, and in consequence of the grey flat-roofed types one saw occasionally put up in charming villages, people became biased against the use of a material which produced a harsh note amongst charming surroundings.

Coloured Surfaces.

I consider that coloured cements will play a big part in the variety which it is possible to obtain from their use in the treatment of the external surfaces. Coloured cement used as a colour-wash enables one to get the endless variety and a permanent finish into groups of houses which are so essential in big schemes in order to divide them into smaller and more intimate units.

Æsthetic Possibilities.

It is not to be expected that concrete houses will wholly take the place of brick ones, but there is no reason whatever why they should not go alongside the older traditions and mark the newer epoch. As the properties of the material are more universally appreciated, and as the engineer, the architect and the craftsman become united in their efforts to achieve the utmost out of its use, concrete houses will then have become established as the house of the future.

Let us not be led away with the idea that concrete in its raw sense is beautiful. Far from it. But let us realise what its possibilities are and make it beautiful, whether it be for domestic work, public buildings, or engineering work, and to do this there must be co-operation between the designer and the constructor.

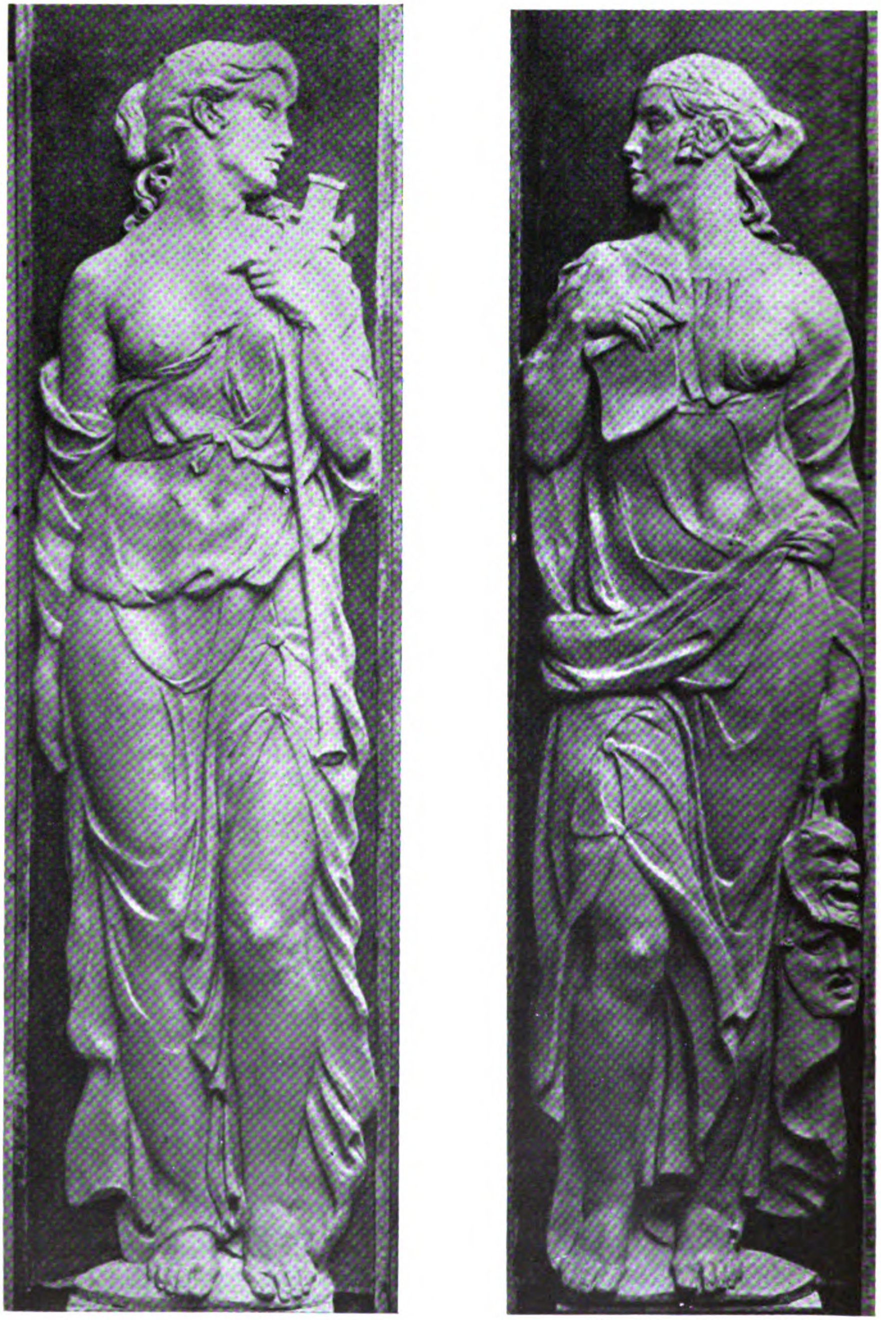
Method of Construction.

I have not touched upon the various methods of concrete construction for houses, as I feel that it matters little how the material is got into position if the one thing to be aimed at is the pleasing effect of the finished building. I consider that forms of construction which tie the designer down to units of size are wrong when considered for small buildings, as designs should not be hampered by construction but rather be helped by it.

Rapid Erection and Cost.

Speed of erection is a strong point in favour of the concrete house; with the use of the present rapid-hardening Portland cements, an unlimited supply of aggregate and labour, there is almost no limit to the rapidity with which these buildings can be erected.

Cost is an item which is difficult to arrive at, and it would be bold to make any definite statement on this point. There is no doubt, however, that this type of construction is no more expensive



[*Mr. Gilbert Bayes, Sculptor.*

"Music." "Art."

Cement Sculpture on Messrs. Brinsmead's New Premises.

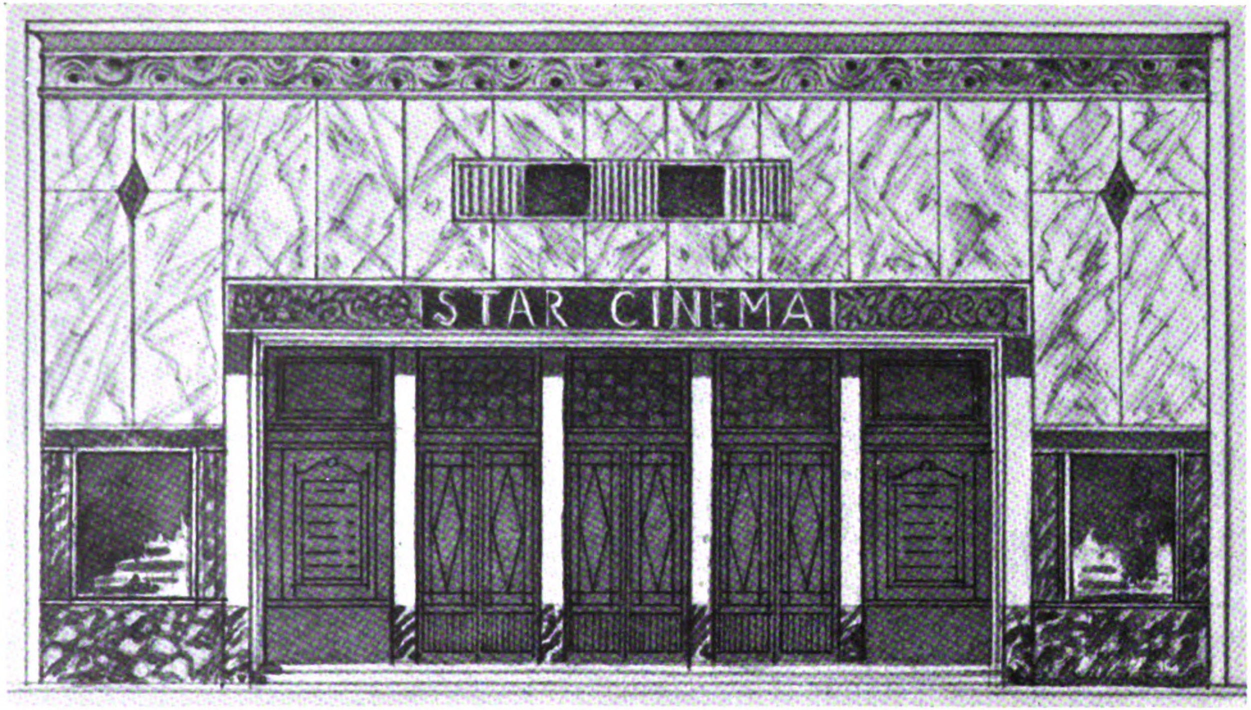
[*Mr. Russell S. Cory, Architect.*

Reinforced Concrete Printing Works in New York.

than brickwork, and I think that as it becomes more universal the balance will weigh in its favour. Where aggregate is readily to hand the price should be more favourable than brickwork.

Durability.

Durability is a point which claims particular attention. I consider concrete houses can be made more durable, more weather-resisting, and with less maintenance than brick houses provided as much care is taken to see that good materials are used as has been taken in the past with all good house building. Shoddy material in this as in other material will lead to defects, and the proper proportion of parts and the strength of the various ingredients require to be carefully studied and not left in the hands of the unskilled.



London University School of Architecture.]

Design for a Cinema in Reinforced Concrete.—By Mr. H. T. Dyer.

The conditions for the competition in which the above design was submitted were as follows: Seating capacity for 300; offices, lavatories, etc.; to be accommodated on a site adjoining two properties and not exceeding 50 ft. by 120 ft. Mr. Dyer has endeavoured to treat the plain surface of a concrete wall by facing it with marble, which shows that a decorative effect can be obtained by applying on the surface of the wall another richer material. Here the expression reflects the structure, and the use of marble in slabs in a certain order allows space for architecturally-framed advertising posters.

Reinforced Concrete in Relation to Present-Day Design.

By **PROFESSOR A. E. RICHARDSON, F.R.I.B.A.**

(Professor of Architecture, University of London School of Architecture.)

DURING the past hundred years the scientific art of building has branched into two main divisions. At first the change was almost imperceptible, beginning with a small coterie of civil engineers who specialised in works outside ordinary building practice; later, responding to the increasing knowledge of the properties of iron and steel, it became definitive. At that time there were some architects who undertook the duties of civil engineers; and engineers such as John Rennie and his son, Telford, Brunel, and the Stephensons, all of whom, within certain limitations, were capable designers. Since that time, especially in this country, the line of demarcation between the professions has become more pronounced. It is now imperative that the two branches of specialised industry should be interdependent.

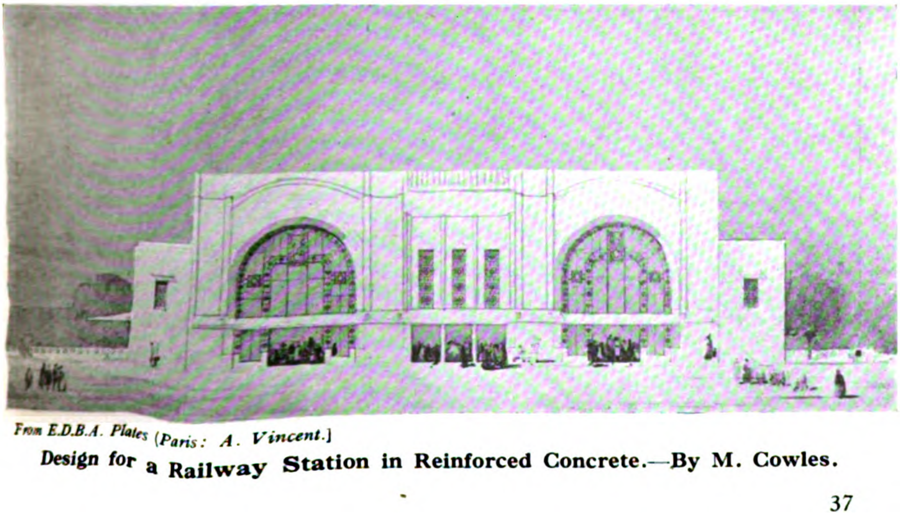
Necessity for Co-operation between Architect and Engineer.

For many years the same traditional methods and almost the same materials were employed by architects and engineers. The rapid development of steel construction at the hands of engineers gave increased scope to architects, but there was no attempt to join forces. Within the last quarter of a century reinforced concrete has led to further experiment on the part of engineers as a prominent factor where economy of construction was desired, and to-day there is scarcely a new building that does not show regard for this system in some of its parts. It is regrettable, however, that architects and engineers collectively have not yet realised the necessity for co-operating to produce improvement of building.

Under present conditions either the architect has to employ materials with which he is familiar, or the engineer only too often evolves works entirely devoid of grace.

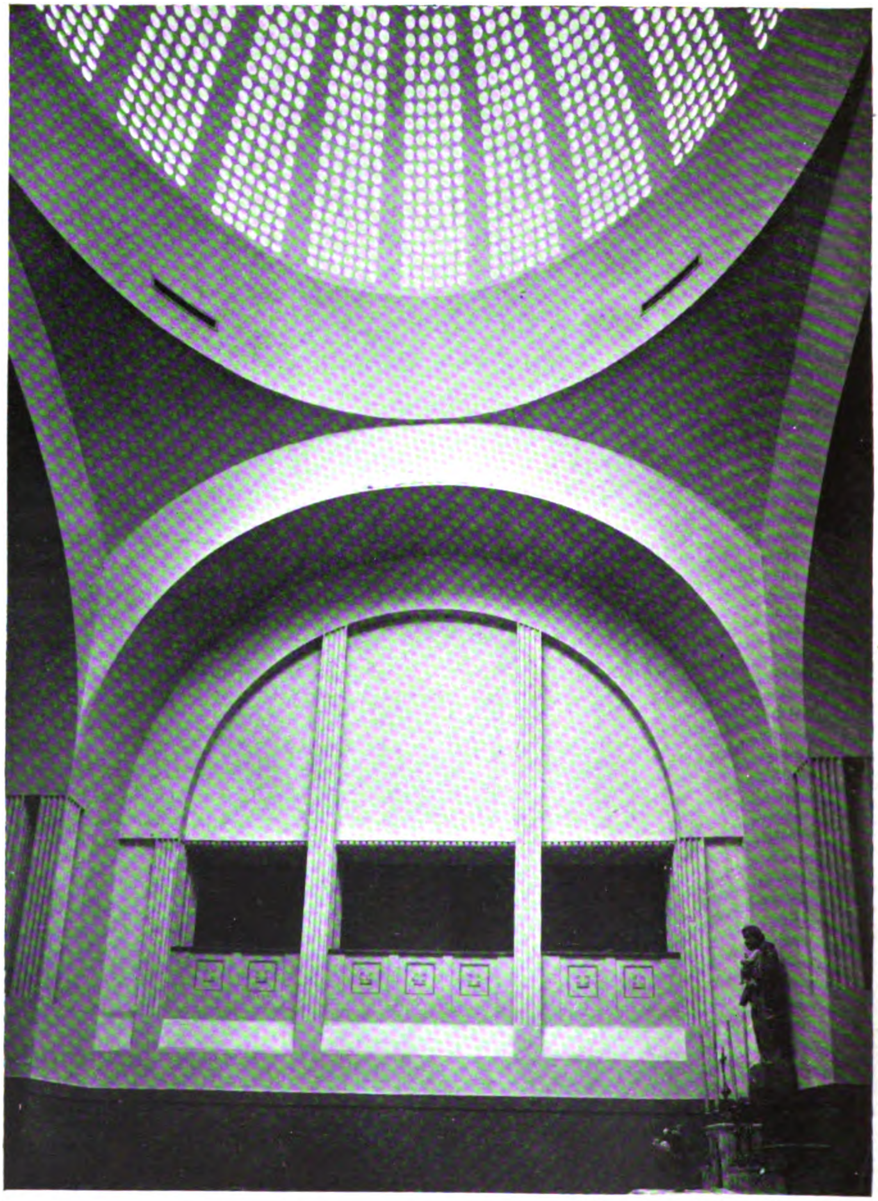
Traditional Methods and Materials.

In ordinary building practice there has been no departure from the materials and the systems of construction in vogue for centuries. Masonry and brickwork, timber, tiles, and slate are used in the manner decreed by tradition. This procedure is to some extent inevitable. There are geographical rulings, craftsmanship, good manners, and local amenities to be considered. Under these conditions, save for



From E.D.B.A. Plates (Paris: A. Vincent.]

Design for a Railway Station in Reinforced Concrete.—By M. Cowles.



[*M. Roux Spitz, Architect.*

Interior of Reinforced Concrete Church at Lyons.

experiment with exotic styles, novelty of design has not been possible. Neither is a complete break with history to be countenanced, for if that were the case art would soon be extinguished.

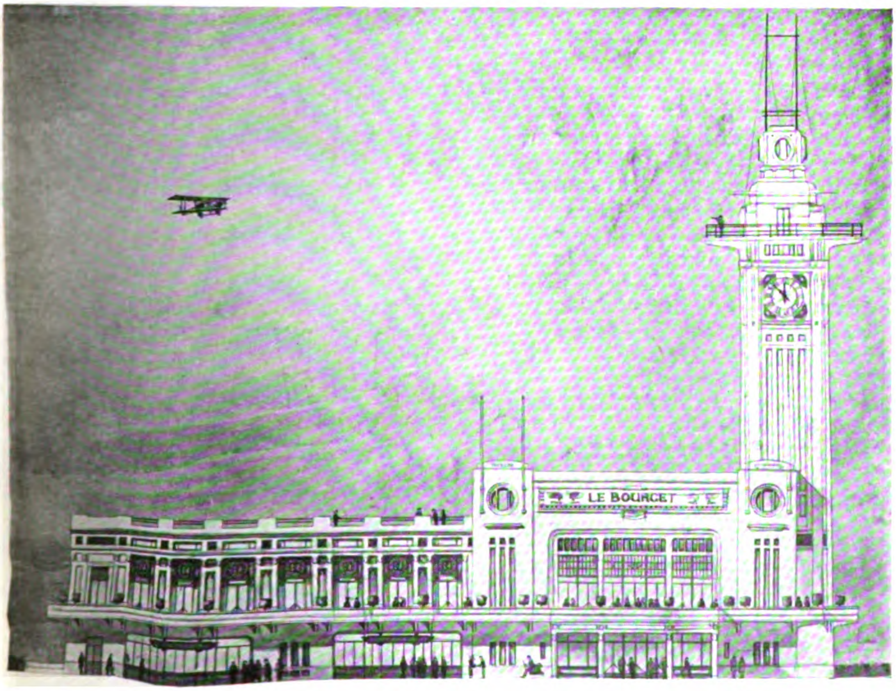
An analysis of the historical development of building shows that materials easily assembled and lightly joined with cement or mortar have resulted in structures depending for stability on the compressive resistance of the materials. It is, however, significant that the conditions of the present day call for a revision of the theory of construction, and especially is this the case where economy of space is valued. The new conditions, and they are legion, demand that complex stresses and forces be met by sympathetic materials having properties of resistance other than those of compression.

Development of Steel and Concrete.

In turn have been developed the composite buildings of steel and masonry, skeleton steel structures, and the building constructed entirely of reinforced concrete. All these types have been in the nature of a compromise. The architect, fettered by style and fashion, has had no alternative but to cloak the skeleton structure with a mask; more frequently than not this has had uniform results and has led to criticism and recrimination. The engineer, bewildered by the confusion of taste in architectural circles, has followed the fashion with results even less convincing. The most curious fact in both cases, almost without exception, is the total disregard of the first principles of building arrangement.

At this stage steel is often more in favour as a constructional medium than reinforced concrete; its properties are generally understood, and it is accepted as part of the system of composite building. The view, however, is held in some circles that the closer correlation of steel with concrete will assist in solving the problem of present-day construction. Be this as it may, reinforced concrete has come to stay, but as yet it is only partially developed.

Concrete is one of the oldest as it is the most valuable of building materials. We



Design for an Air Station at Le Bourget.—By M. G. Hennequin.

have the evidence of the constructive skill of the Romans in this regard ; for example, the dome of the Pantheon, the vaults of the Basilica of Constantine, the anatomy of the Flavian amphitheatre, as well as many other noble works. Vast as these structures were originally, and daring as they were in construction, the structural system then in vogue was far from economical and could not apply today. The use of concrete alone, without reinforcement, would mean a return to Roman methods of building, when compressive resistance was a necessity. The technical considerations of reinforced concrete, now advanced both in theory and practice, belong in bulk to the sphere of the constructional engineer, and this alone is a branch calling for specialised study and high scientific attainment.

But the detailed issues of this modern form of specialised construction, complex, intricate, and purely scientific in its branches, must remain unprogressive without the expert knowledge or skill of the trained architect in matters essentially architectural. Hence the need for the immediate recognition of both sides of the issue, the amalgamation of forces, and a clearer understanding of the structural, and thereby the architectural, aspect of the case.

Experience of the work of architects and engineers has shown the timidity of the first when new constructive methods are available, and the reluctance of the latter to recognise the difference between fine building and mere building. Hence has come about the delegation of reinforced concrete almost solely to the purpose of utility building, which is as lamentable as it is illogical.

In other countries—France, Italy, Germany, and America—the line of demarcation between the kindred interests is less pronounced, but nevertheless it exists.

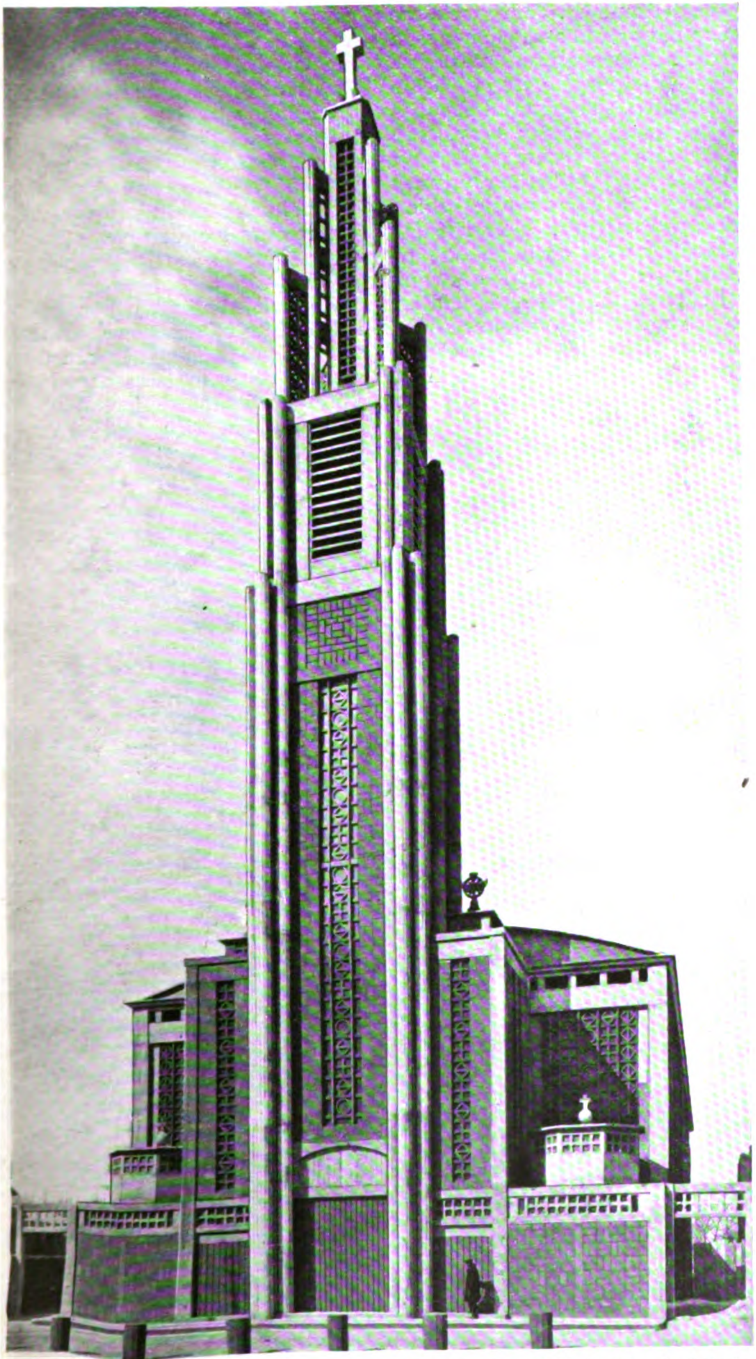
While most text-books make available in the most concise form the best data for constructing buildings of reinforced concrete, these are in the nature of working manuals. A real service would be rendered to both architects and engineers if a book were to be compiled giving photographs and scale drawings of the different types of buildings already in being in which this excellent material is prominent. Save for occasional illustrations in the various technical papers, there is little record of what has already been accomplished. On this showing the need for a reference book containing something more tangible than technical data becomes apparent. For the purpose of this article a short explanation is necessary to define the functions of the architect in matters of design, independent for the moment of questions of materials and principles of construction.

The Function of the Architect.

The architect is more than a decorator ; he is a deviser of structures. His work begins with the analysis of the conditions governing a projected building. His training enables him to sort out the parts of a scheme, to settle the main axes of a plan, and to group the resultant spaces in sequence. In the case of simple buildings this task is not difficult, but when many plan features have to be cast into a pattern, either symmetrical or asymmetrical, the highest planning facility is necessary.

In itself the theory of planning is a life's study. Technical requirements change very rapidly, and for each special type of building a new set of technical conditions has to be mastered and adjusted. The theory of planning—in other words, the theory of structure on the horizontal plane—from the architectural point of view is closely related to the history of building through the ages. It is not that an architect feels compelled to follow precedent before he begins a plan in embryo, but he gains increased confidence in his power to arrange and dispose of spaces if he is fully acquainted with past achievement. Beyond squares, rectangles, circles, and octagons, with combinations of these figures, invention is, of necessity, circumscribed.

For buildings of complex type the science of planning is all-important, and the architect who is a fine planner occupies a very high place in the estimation of his colleagues. There is a great difference between crude arrangement and planning on æsthetic lines ; this is a truth recognised in France and America, and it places the architect, by virtue of his specialised training, on a plane equal to the engineer. The plan in its precise development, the result of trial after trial, connotes the structure in three dimensions. It is design in the abstract. No one can say at what stage the final pic-



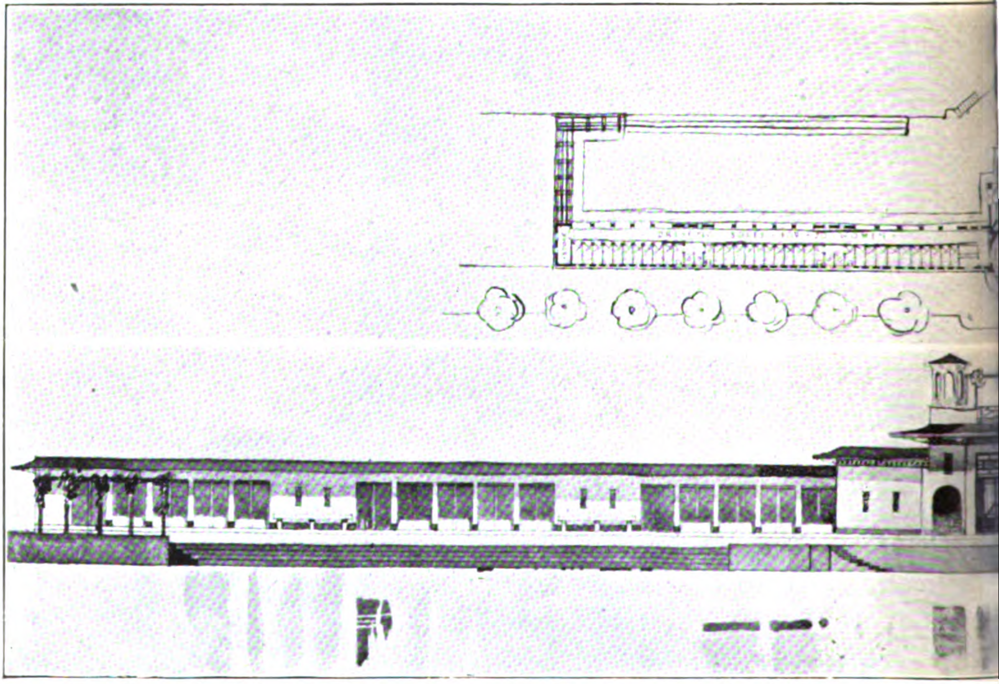
[MM. A. and G. Perrett, Architects.

Reinforced Concrete Church at Le Raincy, near Paris.

torial effect is determined. If the scheme is satisfactory in its axial arrangement, in the geometrical sequence of its parts and its suitability to the purpose for which the building is intended, the pictorial effect is assured. The true architect keeps the scheme fluent in its embryonic stages, and is prepared to recast the plan many times before effecting the compromise which approximates to the truth. So far it has not been necessary for such an one to consider either constructional data or ornamental expression. Stress is laid on the importance of the foregoing procedure, because in most circles little acknowledgment is given to the architect's skill in this regard.

An engineer, on the other hand, confronted with a complex planning problem generally follows the line of least resistance and plans directly without observance of the laws of architectural planning. The resultant effect would lack the grace and consistency so desirable to works of the first rank. Time and again is this fact demonstrated in works devised and built without architectural supervision. The embodiment of a structural system in architectural design is the first essential, and this is entirely the architect's province.

Specialised construction and a knowledge of its factors comes into force when the design exists on paper in three dimensions. With modern knowledge of the known laws of design, and a working acquaintance with steel and concrete as well as of other materials, the architect



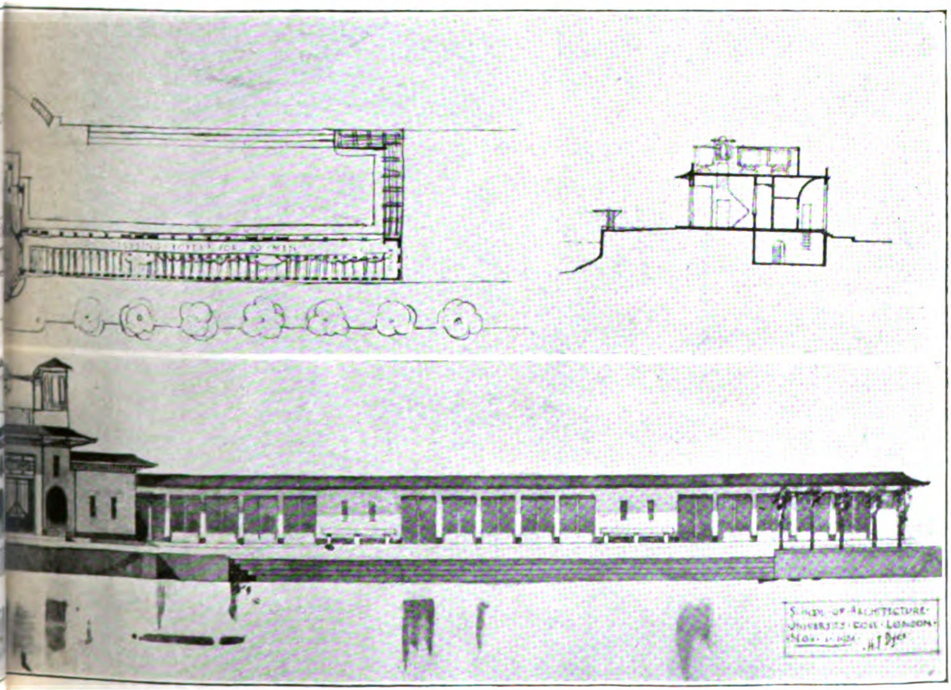
University of London School of Architecture.]

Design for a Riverside Bathing Establis

In this competition the student answered to one of th main conditions of the programme, viz. "the entran hall must have separate entrances for men and wome with pay-box common to both sexes." The architectur treatment is rather pleasant and suitable to the site. F a permanent structure of this type concrete is a ve next determines the structural points which become accents in the three-dimensioned designs. He is conversant with the rules of scale, proportion, and rhythm, and he concentrates on producing a scheme in which homogeneity is the main issue.

Such a summary as the above shows how the trained and disciplined architect compares most favourably in status with the trained engineer. The two provinces are distinct, but they have an affinity. In a building of vast size, having problems of construction to be interpreted in an economical manner, the engineer functions in a definite capacity. This is the general practice in America, France, and other countries, and it is rapidly gaining acceptance in England.

With the prevalent methods of building partly with traditional material and partly with steel, no great advance towards originality of effect has been achieved. There have been variations of surface effects, and to some extent a revision of planning, but it cannot be said that an economical departure which is architecture has been brought about. Architects and engineers have so far failed to meet on common ground. In the one case decorative issues have led to the obscuring of structural vision, and in the other direct construction has been an obsession to the exclusion of æsthetic values. Both parties have failed to develop the elementary theories of structure which were never absent from the masterpieces of the past.



Reinforced Concrete.—By Mr. H. T. Dyer.

logical material to use, and the fact that with concrete beams the spanning of voids has a special proportion shows how a building can obtain a definite character which, while avoiding proportions to which we are used in brick and stone structures, expresses the material of which it is constructed.

Reinforced Concrete Bridge in Switzerland.

This article outlines the intensive training of architects and emphasises the specialised studies which will continue to form architectural training. The purpose is twofold: first, to show that the architect is something more than a decorator, and second, to prove the need for engineering assistance. Except in rare cases, neither the architect nor the engineer is qualified to undertake both duties.

Possibilities of Reinforced Concrete.

With the advancement of architecture, or building as a scientific art, there has concurred a desire for economy of design both in planning and effect. This in turn has led quite naturally to a demand for pictorial expression emancipated from the trammels of style and period. Traditional materials do not admit of more than surface variations from precedent, but the use of reinforced concrete allows for expansion of time-honoured theories without loss of qualities which are of the very fibres of architecture. Evolution in building design is bound to be slow, but its effect cannot be other than cumulative.

There are many who appreciate the value of ferro-concrete as a material for modern building. It is a pity that so far its use has been limited to utility buildings. The issue of fine planning remains constant, the theory of dimensioned structure will remain in the hands of the architect, but it is not to be expected that architects as a body will do aught else but rely on expert advice where questions of integral calculus are concerned.

The uses of concrete are manifold, and the way has within the past decade been opened to architects for a revised system of design which admits of a definite advance. The new theory is at present somewhat indefinite, it lacks articulation, the touch of imagination which is the spirit of art. No matter how well the details of construction are thought out, the pictorial effect so long desired will not be achieved entirely by the attributes of mere construction.

The designer in ferro-concrete has to master the wall and pier forms for buildings and bridges; these in part have already been determined by experience. He must be conversant with the manufacture and use of concrete blocks. He must know of the use of wood moulds, and facing materials suited to ferro-concrete walls. The distribution of stress in homogeneous beams and the forces to be resisted by rectangular beams and slabs equally demand knowledge on the part of the architect. Then there are the column types, plain and reinforced, the most important compression members in buildings of this character.

The theory of moments in rigid building frames belongs to the province of the engineer. In this country, so far as ordinary building practice is concerned, ferro-concrete is at present largely reserved for foundations, floors, roofs and stairways. There are, of course, instances of the entire use of ferro-concrete for factories, swimming baths, tanks, water towers, reservoirs, the buildings at Wembley, etc., but the general adoption of the material for architectural building is still awaited.

Scientific structure without graceful statement is as bad as architectural pedantry. For example, a girder viaduct with its many supports could be made a

Reinforced Concrete Bridge in Ireland.

thing of joyful expression. The battered lines of the piers, the projecting footways and the parapet, the very junctioning of the homogeneous material, offer the most valuable opportunities for the pencil of a skilled designer. There are cantilever bridges, which in appearance approximate to concrete arches, and concrete abutments for steel bridges. Arched bridges constructed of reinforced concrete are of many types, ranging from the historic forms with filled spandrils to those with open spandrils, and there are also hinged arched bridges. Hydraulic structures, such as reservoirs, very rightly belong to the province of the engineer. Finally, we must consider the design of deep grain bins and silos.

The Need for Example.

Architects are naturally conservative, and especially is this the case where a new material is concerned. While the advantages of reinforced concrete construction are apparent, as offering a means whereby an existing system of design can be expanded almost without limit, for want of illustration things move slowly. Is it not strange that the most scientific method of construction yet advanced has not found deserved support in this country? At all stages of its history building has responded to some influence extraneous to ordinary routine. At this juncture, when the desire is expressed on all sides to meet modern conditions in an efficient manner, it is not sufficiently realised that a new architectural expression is only consonant with the employment of a new system of construction. Such reasoning, as I have been at pains to show, does not alter the general rules of structure; on the contrary, it allows of their recognition and expansion. The architect's position as a deviser of structures remains unaltered; he must still be versed in history, in art and culture; he is still the historian of his time. Moreover, he is not precluded from combining traditional materials with the new and revised system of concrete for building.

The Material of the Future.

The architect from time to time will be called upon to interpret changing conditions affecting different types of buildings; he will in the future, as in the past, have to contend with technical considerations outside the sphere of construction.

Ferro-concrete is the material of the present and the future. By its aid the principles of geometry in building can be stimulated ; it will become possible to span openings of a greater width than at present ; to erect domes transcending the scale of the Pantheon and of the dome of Santa Sophia ; to build churches and cathedrals of an interest rivalling the glories of the Middle Ages.

As time progresses new methods of surface treatment will be invented, and offer a stricter regard for truthful expression and an entirely new system of proportions. For small houses and cottages there is everything to be said for concrete. It may be found essential to have recourse to traditional materials for roofs and for other minor parts, just as it is expedient at present to build small houses of concrete blocks.

One thing is foreshadowed exceeding anything else in importance, and that is increased freedom of design in planning. Reinforced concrete does not exclude the use of facing materials, neither does it imply the discarding of marbled surfaces for interiors, or the abandonment of decorative accessories. On the contrary, as the knowledge of the material is developed newer systems of decoration will come into force. Architects must, however, concede to this material, and to the science which has brought it into prominence, the fact that its employment calls for an observance of its physical properties. It would, for example, be absurd to clothe it with copy-book detail, just as it would be similarly erroneous to follow the Roman system of construction with its extravagant use of material. Engineers on their part must come to a fuller appreciation of the training and the functions of the architect—the one profession cannot advance without the help of the other.

Concrete and the Architectural Schools.

Most architects and engineers are conscious of the fact that design without resistance, other than the making of fantastic pictures, is practically impossible. It is also clear to me that before long some attempt of a serious nature must be made to define the possibilities of ferro-concrete design other than those put forward by technicians. Both parties are awaiting a lead.

A way out of the difficulty is suggested by making the design of ferro-concrete buildings, of different types, part of the advanced training in the schools of architecture. Prizes might be offered by concrete firms to be competed for annually by students especially trained to deal with this material. The result would be interesting and helpful.*

The main theme of this article points to the need for fuller recognition from engineers of the specialised training of the architect as an inventor of buildings, just as it suggests to the architect that at a certain stage he must call upon the expert to assist in interpreting the constructional details. The architect, however, must have sufficient experience of the material he is employing in his design to appreciate its capabilities and physical properties.

Scientific knowledge, however profound, does not entirely satisfy. Of itself it is insufficient to supply the spark of genius, in other words, the imagination which alone ensures a building being out of the ordinary. Architecture is not, and never has been, mere decoration. A wider acceptance of the term structure is a necessary corollary to the development of a new principle of construction, which in turn by zealous experiment will lead to new expression. Cause invariably precedes effect.

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* On page 6 we announce that the proprietors of *Concrete and Constructional Engineering* have given a yearly prize of the value of £25 for a competition in reinforced concrete design at the University of London School of Architecture.—Ed.

Twenty-one Years of Concrete Development.

By **OSCAR FABER, O.B.E., D.Sc., M.Inst.C.E.**

In commemoration of the twenty-first birthday of the journal in which this article appears, it is perhaps not out of place that various writers should refer to the development of concrete engineering which has taken place in this period. No doubt various contributors will view this from somewhat different standpoints, and what appeals to one may not appeal so forcibly to another.

Twenty-one years ago the use of concrete was practically confined to foundations, dock walls, retaining walls, and other structures where the material is used in considerable bulk and where the stresses are very low, and in many of the structures such as retaining walls and dock walls sufficient cement has to be used to make the stone particles hang together so that the wall will act as a single mass, but above this comparatively small strength is necessary.

Undoubtedly one of the outstanding changes that has taken place is the use of concrete sufficiently rich in cement to be watertight, which has rendered possible the development of reinforced concrete. Reinforced concrete is unthinkable as a material except in conjunction with a concrete substantially watertight and airtight and, including as it does reinforced concrete roads, floors, retaining walls, and the hundreds of other uses of concrete in connection with building, it is not too much to say that this has opened up a new field of concrete which twenty-one years ago had hardly been thought of.

Improvements in Portland Cement.

The improvement in Portland cement in the period has been phenomenal, and many people do not realise that cement has improved more in the past four or five years than in the twenty years preceding. This is perhaps well illustrated by the British Standard Specification.

The following short table shows the strength of 3 to 1 sand cement specimens in seven days required by the British Standard Specification of the various years referred to :—

Strength of 3 to 1 specimens in 7 days.

Year of B.S.S.	lbs. per sq. in.
Dec., 1904	120
June, 1907	150
Aug., 1910	150
Mar., 1915	200
,, 1920	200
,, 1925	325

Although from 1904 to 1920 the increase was only from 120 to 200 lbs. per sq. inch, the increase from 1920 to 1925 is from 200 to 325 lbs. Yet remarkable as this increase is, it does not gauge the extent of this development. This is evident from the fact that we have to-day special cements, such as rapid-hardening "Ferrocrete," in which the 3 to 1 seven-day tests can be guaranteed at 600 lbs. per sq. inch. This figure compared with those in the specifications shows very graphically the real advance.

To many people rapid-hardening cement is associated only with increased strength in the early stages of setting, say up to a week or two in age, but actually the advantage of this material continues to exist even when it is a year old, and several tests show quite clearly that even after a year the results are frequently 60 per cent. or more over and above the corresponding results with ordinary cement which complies with the British Standard Specification, so that this cement must be looked at not only as rapid hardening but also as a cement giving greater strength at all stages than ordinary Portland cement. This result is achieved by an increase in the lime contents which is rendered possible without producing an unsound cement by the much finer grinding to which it is subjected.

Cements of this kind have made it possible to construct concrete roads which can be opened to traffic, without damage to them, a few days after they are laid, whereas ordinary cement requires weeks to attain the same strength. The importance of this under modern traffic conditions is tremendous.

A review of this kind would also be incomplete if it did not refer to the so-called aluminous cements, which give greater strengths and much more rapid hardening still, though at a considerably increased cost.

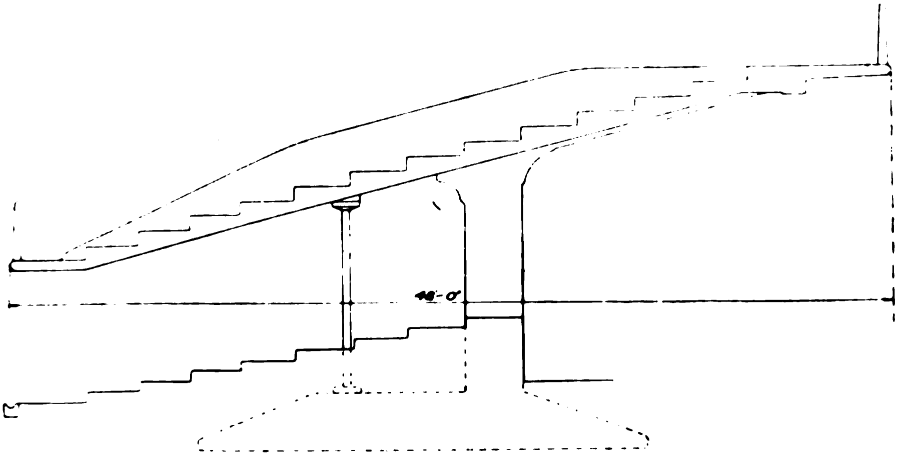
Whatever one may think about the wisdom of constructing ships of reinforced concrete—and it will be well to be frank here, and say that I do not consider reinforced concrete the right material to use for this purpose—the fact that reinforced concrete could be used for this purpose at all in the way that has actually been achieved represents a technical advance and a demonstration of skill in the use of the material which cannot be overlooked. To construct these great vessels with walls often only 2½ in. thick, absolutely watertight even under the severe stresses to which they were subject, a stress alternating from tension to compression according as the wave formation produces positive or negative bending moments, and weighing only somewhere between 60 per cent. or 100 per cent. over the weight of a steel ship of equal size, is indeed an achievement to be proud of even if commercially it may be unsound, as I believe it is.

Concrete Houses.

It is impossible not to mention the attempts to use concrete instead of brickwork for houses, attempts which have been generally successful but not universally so. It does not seem to be sufficiently realised that concrete without brains directing it in all stages from design to execution is only so much inert material entirely free from magic. People speak of concrete as if it were one material, instead of being a generic name covering an unlimited number of mixtures, in which not only may the proportion of cement be varied within very wide limits, but the materials with which it may be mixed are also extremely variable. In the hands of a skilful technician the variations which result can be utilised to advantage. In this way concretes can be produced for houses which, while resisting rain on the outside, permit of

[Oscar Faber, O.B.E., D.Sc., M.Inst.C.E., Engineer.

Reinforced Concrete Grand Stand at Lord's Cricket Ground.



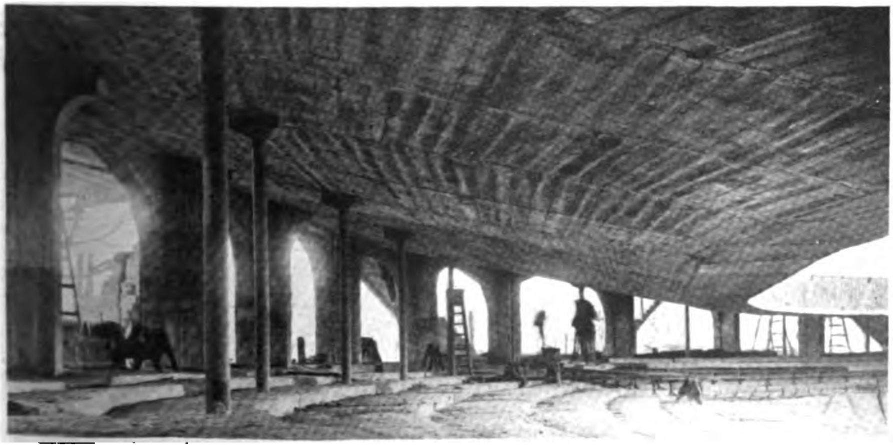
[*Oscar Faber, O.B.E., D.Sc., M.Inst.C.E., Engineer.*

Reinforced Concrete Grand Stand at Lord's Cricket Ground.

the absorption of condensation on the inside. In the same way the material, normally a good conductor of heat, can when scientifically handled as in cellular concrete, be made one of the finest insulators. In the same way the material, normally weighing about 150 lbs. per cu. ft., can be reduced in weight down to a material which easily floats.

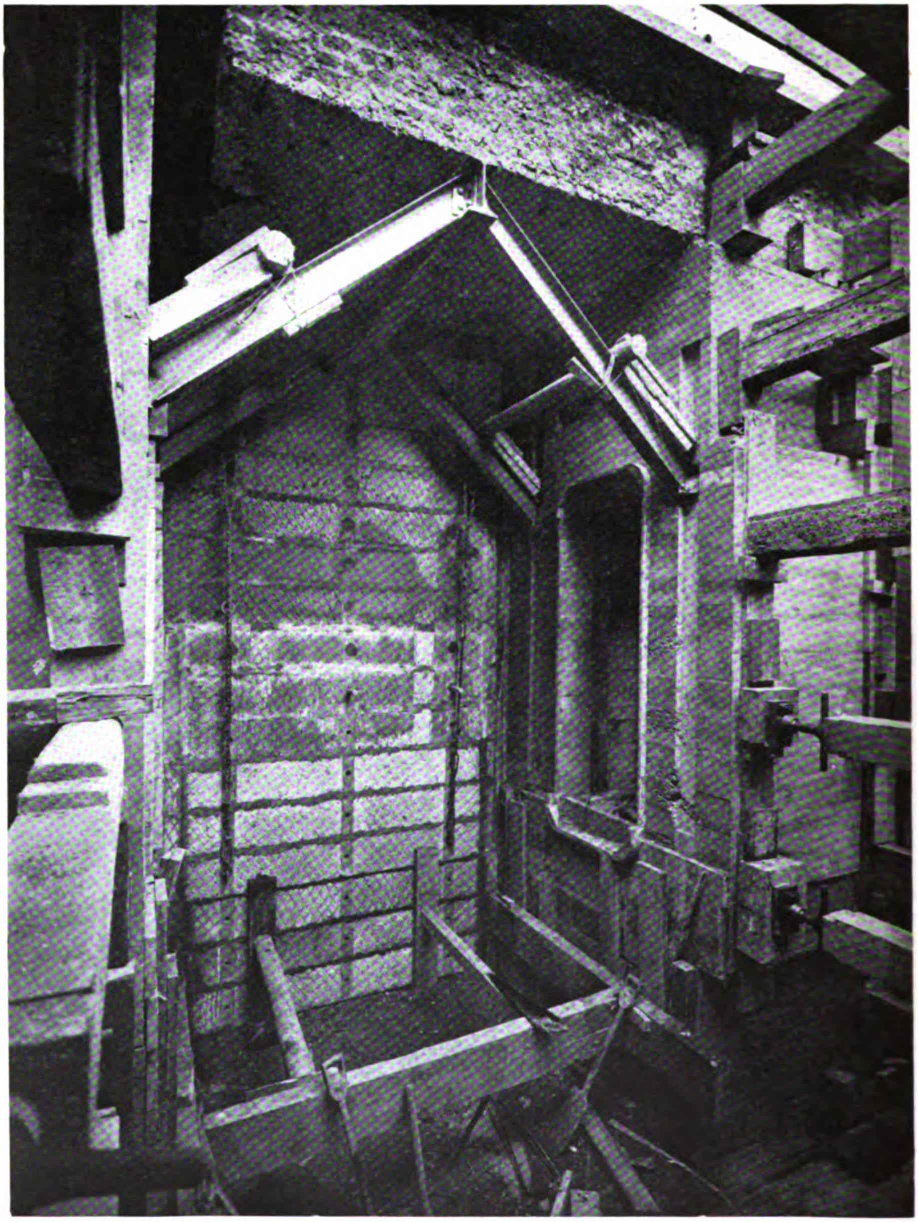
New Materials.

In this connection some mention ought to be made of concrete made with sawdust as aggregate. Many attempts were made some years ago to use cement and sawdust in combination, and the results were very unsatisfactory. When, however, the sawdust is chemically treated or mineralised a product is obtained combining the strength of ordinary concrete made with sand or stone with only half its weight, and with the further properties of being readily cut with an ordinary saw, readily drilled for taking screws or nails,



[*Oscar Faber, O.B.E., D.Sc., M.Inst.C.E., Engineer.*

Reinforced Concrete Grand Stand at Lord's Cricket Ground: showing the uninterrupted view due to the absence of columns in front.



[Herbert Baker, A.R.A., Architect; Oscar Faber, O.B.E., D.Sc., M.Inst.C.E., Engineer.

Reconstruction of the Bank of England: R.S.J. Strutting to old Wall.

warm to the hand or to the foot and therefore very desirable for wall and floor surfaces, and, for pavements, combining excellent wearing qualities with a non-slipping surface.

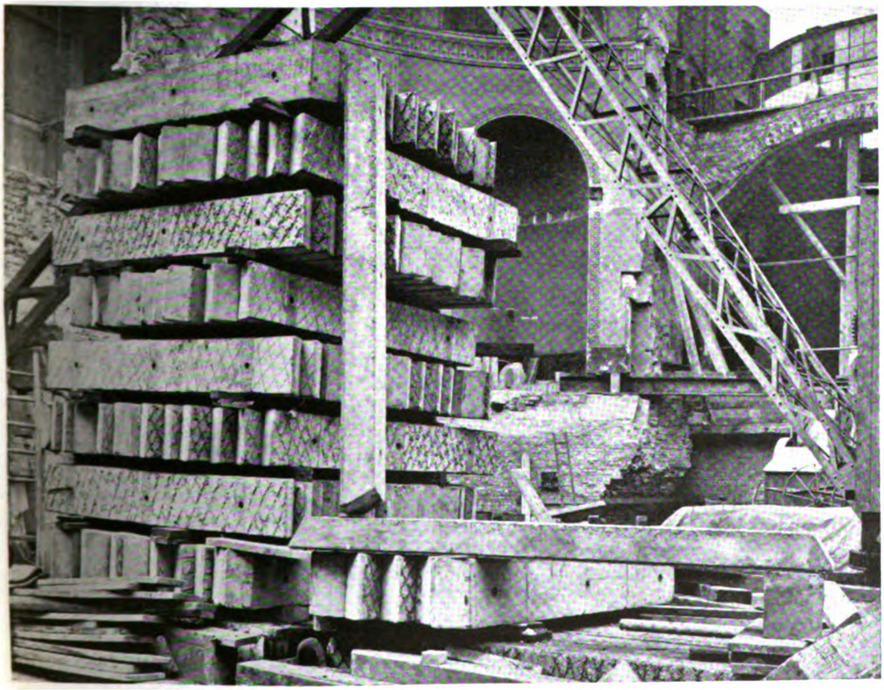
With modern materials at our disposal, with these advances over what we had before, it would be surprising if modern engineers were not able to produce notable structures, and there are no signs that they are slow to take advantage of these materials, except perhaps when the municipal regulations so often lag sadly behind.

It seems indefensible that, with the tremendous advance in the strength of concrete, 600 lbs. per sq. in. should still be considered the magic figure for which all concrete is to be designed. Surely if this figure were a safe figure in 1915 when the British Standard Specification only required 200 lbs. per sq. in. as the strength of the cement, then this figure requires to be considerably increased in 1925 when 325 lbs. per sq. in. is demanded.

A Joint Committee representing four well-known societies interested in reinforced concrete has recommended that this figure be raised to 750 lbs. per sq. in., and this advance appears to be conservative and overdue.

New Stand at Lord's.

Two photographs and a drawing are published, by kind permission of the M.C.C., showing the new stand at Lord's Cricket Ground. As will be seen from the photographs and the drawing, this stand provides for stepped seating at two stages. The lower stage rests on the ground, and the upper stage consists of a reinforced concrete structure supported in a novel manner. In nearly all stands of this kind the vision of the spectators is interfered with by a series of vertical posts in the front. Even when these are kept as small and as few as possible, they do, in the case of a game like cricket, cause appreciable disturbance to the onlookers.



Herbert Baker, A.R.A., Architect ; Oscar Faber, O.B.E., D.Sc., M.Inst.C.E., Engineer.

Reconstruction of the Bank of England : Walings for retaining Wall stacked on Ground.

The writer had the pleasure of collaborating with Mr. Herbert Baker, the architect for this work, and suggested the construction which is herein described, whereby the upper structure would be cantilevered over in such a way as to avoid the necessity for such supports altogether. This suggestion was warmly encouraged by him, and the construction has actually been carried out on these lines. It was desired to keep the stand as close to the ground as possible, and for this reason the cantilever beams are placed above the upper stepped seating instead of below it. They form useful barriers between the various sections of the seating and structurally form in combination with this seating inverted **T** beams.

This work, which was carried out by Messrs. Trollope & Colls, Ltd., as contractors, in the remarkably short time of four months (from Christmas to April), out of which much time was lost by frost, shows that properly organised reinforced concrete need not be the slow procedure that some people believe it to be.

Rebuilding the Bank of England.

Another interesting development is in connection with what has hitherto been called "timbering," but for which a new word may have to be found.

In the past, where it was necessary to construct a retaining wall in ordinary soil, the vertical face was retained temporarily during construction by poling boards, walings, and struts, all composed of timber. In the case of retaining walls to buildings where the lower stories have to be kept dry it is usual to resort to vertical asphalting to form a watertight seal around the whole of the area below ground. The common method of construction is to remove the bottom frame of timbering, build against the earth a brick or concrete wall to receive the asphalte, asphalte this for a height of 3 ft., construct the concrete retaining wall behind the asphalte up to this level, and then proceed with the next vertical layer 3 ft. high in the same way, repeating the whole of these operations every 3 ft. until the work is done. Not only is this a lengthy proceeding, but the timber, unless this is to be lost, has to be released, and leaves the earth unsupported in sections for short periods of time. Tests have shown that earth treated in this manner generally "gives" a little, which may result in cracks in the street with consequent damage to water and other mains, and some damage and settlement of surrounding property may also result.

A new method of underpinning was evolved for the rebuilding of the Bank of England, for which the writer is Consulting Engineer, with the object of getting over this difficulty, and has proved very successful. In this, concrete walings 12 in. by 6 in. in section and roughly 7 ft. 6 in. long are placed against the earth instead of timber. These are strutted back at the sides, and when the hole has proceeded to the bottom a vertical face is provided, against which the asphalte can be placed from top to bottom in a single operation without releasing any timbering at all. These walings are made of rapid-hardening Portland cement, enabling them to be handled quite young. In the case of the Bank, where there is 1,500 ft. run to underpin in this manner through a great depth, it is estimated that two years have been saved by the adoption of this method.

The drawing and two photographs, reproduced by kind permission of the Bank, show the two types of walings which were used, Type "A" being used in the alternate holes which were first excavated, concreted, and pinned up; and Type "B," which were used in the intermediate holes. It will be seen that Type "B" walings are supported by the cantilevered projection of the ends of Type "A" walings, and enable the asphalte in the first series of holes to be picked up before the second holes are concreted, and so to make a perfect asphalte joint. Another advantage of this method of construction is that the whole of the vertical asphalte can be placed before the reinforcing rods are introduced, obviating the necessity of asphalting behind reinforcement, which is one of the drawbacks of the older method. Another advantage still is that the space between the walings and the earth can be grouted under pressure as the excavation proceeds, so filling up the slightest crannies and preventing settlement of street or buildings, and this earth so supported is not at any time released.

Reinforced Concrete in Dock Works.

By **F. E. WENTWORTH-SHEILDS, M.Inst.C.E.**
(*Docks Engineer, Southern Railway.*)

Concrete at Southampton Docks.

DURING the past twenty-one years a large amount of Portland cement concrete has been used at Southampton Docks for various purposes. The quay walls of the Ocean Dock, which are among the largest in the world and which have a height of 74 ft. from cope to foundation, were all built of this material. The bulk of the work was carried out in the dry, the concrete being moulded *in situ*. Some parts of the walls were, however, built in deep water, in which case they were faced with pre-cast 6-ton concrete blocks, handled by a titan crane and laid by helmet diver; the hearting of the wall being deposited *in situ* under water by being lowered through the water in special bottom-door boxes.

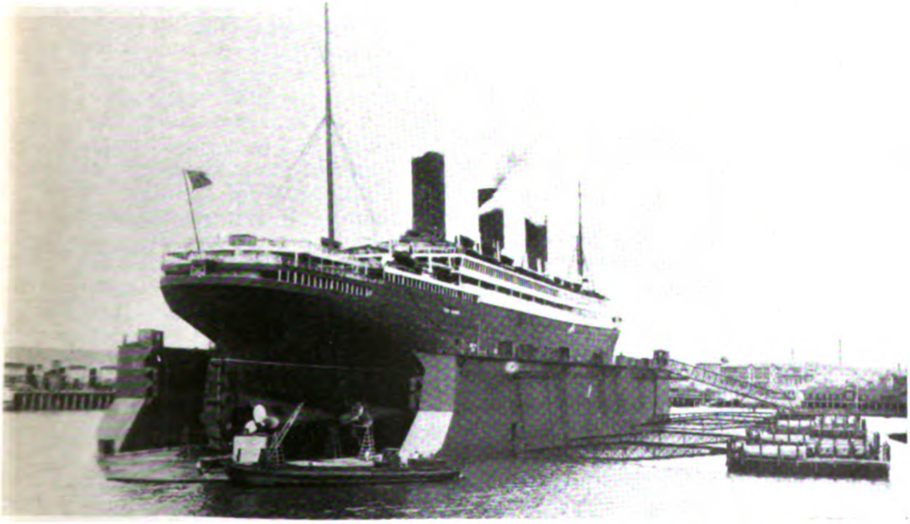
Precautions to Prevent Deterioration.

Several works have also been constructed in this period in reinforced concrete. At the Port of Southampton is a wharf owned by Messrs. John I. Thornycroft & Company which is the oldest marine reinforced concrete structure in this country, having been built in 1899. It is still standing, and in excellent condition.

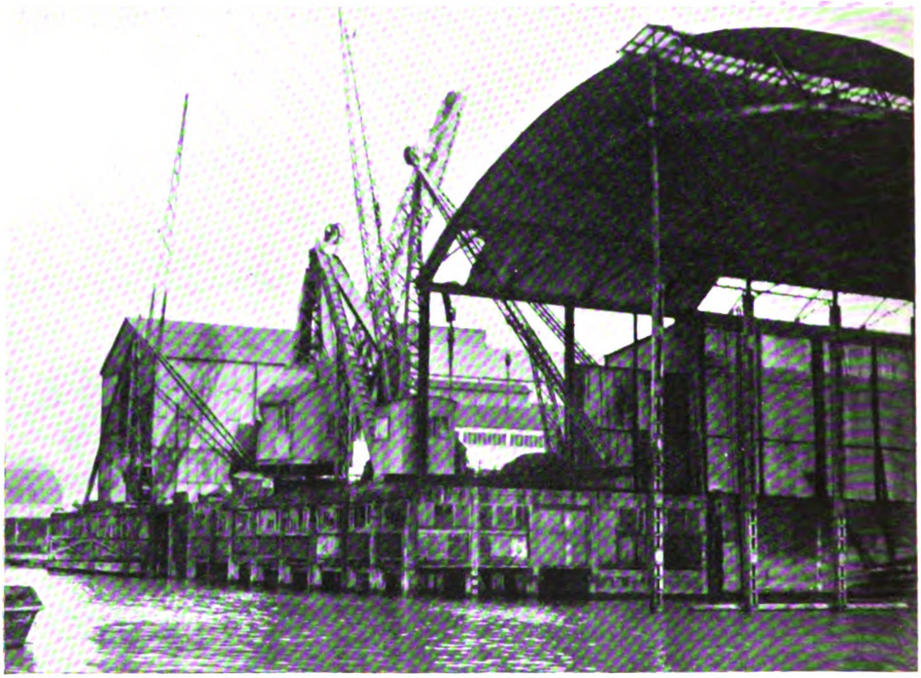
Some reinforced concrete quays which have been built since that time, however, have suffered deterioration above water-level owing to the rusting of the steel inside the concrete. In one case the deck has been renewed and several improvements have been introduced. The design of the deck was stiffened and a richer mixture was used (1 : 1·8 : 2·4). The cover of concrete over the steel was increased 2½ in., and the whole of the deck was coated with tar. These precautions seem to have been successful; parts of the deck are now ten years old and in quite good condition.

A 60,000-ton Floating Dock.

An interesting use of reinforced concrete was made in connection with the Southern Railway Company's 60,000-ton floating dock. The four dolphins to which the dock is moored are made entirely of this material; each consists



60,000-ton Floating Dock at Southampton: Moored to Reinforced Concrete Dolphins.
(*An isometric view of these Dolphins is given on p. 62.*)



Reinforced Concrete Wharf at Southampton: built for Thornycroft's in 1899.
(The first reinforced concrete sea-water structure built in Great Britain.)

of a slab, 70 ft. by 32 ft. by 5 ft., resting on 94 piles, 44 of which are vertical, the remaining 50 being sloped at 30 deg. in all four directions. The slab stands about 20 ft. to 37 ft. above ground level, and the push or pull from the floating dock is estimated to be about 250 tons. The raking piles, however, keep it perfectly rigid. The weight of each dolphin is about 1,500 tons.

Repair of Dock Gates.

Reinforced concrete has also been used for many other purposes. In one case it was adopted for the repair of an old Bramley Fall stone gate sill in one of the dry docks. The sill had become crushed by the pressure of the gates, and was successfully cut out and replaced with the new material which was able to withstand induced tensile stresses which the stone could not resist.

The Portland cement used has all complied with the British Standard Specification, and, indeed, has been of very much stronger quality throughout than this specification provides.

Future Developments.

In connection with the new scheme of Dock extensions which are contemplated by the Southern Railway Company on the Western Shore, Southampton, it is proposed to build reinforced concrete jetties for accommodating the largest liners. These jetties will be about 1,150 ft. long and 260 ft. wide, and will have a depth alongside of 45 ft. at L.W.O.S.T.

There is no doubt that reinforced concrete has opened up a new vista of possibilities for the engineer, and the variety of uses to which it can be put is by no means exhausted. Certain it is that to be satisfactory reinforced concrete must be made with great accuracy and care, and a little additional time and trouble spent in the early stages will be amply repaid by a longer life. I think the use of concrete for "domestic" purposes has been limited partly because of the appearance of some of the finished structures and articles; with more pleasing design and the use of colour a much more attractive appearance should be ensured, and a still more widespread use obtained.

Some Notes on Concrete.

By E. C. HANNEN.

(Chairman, Holland & Hannen and Cubitts, Limited.)

LIKE all new developments, reinforced concrete has had to combat both scepticism and prejudice. During the initial stage its progress was due to the energy and enthusiasm of a few specialists with faith in their subject, and to the courage of a small number of building owners willing to take risks for the sake of economy and progress.

Pioneer Experiments.

On the subject of this pioneering age I can write from first-hand knowledge, as my Company was among the small band of enthusiasts who devoted much time and money to experiments. The available formulæ were few and unreliable. There were no rules—except perhaps the good old "rule-of-thumb." We proceeded on a system of trial and error, and I am afraid the latter was conspicuous by its presence, but still it is possible that more was learnt from the failures than from the successes. At that time we were reading of the Monier, Coignet, Hennebique and Considère systems in France, and the Kahn system in America, and my Company carried out a series of practical tests in our own laboratory in most of the systems, under the auspices of Professor Unwin.

While the industry was still in its infancy I remember looking up to Messrs. Stuart's with frank admiration as they were bold enough to bring out a cut-and-dried system of their own, and persuaded many customers to adopt it for floors, in the place of the old filler joist method, with marked success.

This phase was of necessity slow, and would in all probability have been much slower but for the advent of the war, when a substitute had to be found for the commoner building materials of brick and steel. This young and virile industry was quick to make use of its great opportunity, and a vast number of excellent buildings were erected in reinforced concrete and proved themselves to be both efficient and economic.

Quite naturally this period of "substitution" brought with it some instances where reinforced concrete was used and was not suitable for its job. This was due in part to necessity, and also in a large measure to lack of experience. Nevertheless, in spite of inevitable setbacks, the progress was real and substantial. Even the cases of misapplication proved beneficial. It meant an early winnowing of ideas, from which emerged the fact that reinforced concrete was not a "substitute" but a specific building material with very definite uses, and worthy of an architectural treatment all its own.

Concrete and Architecture.

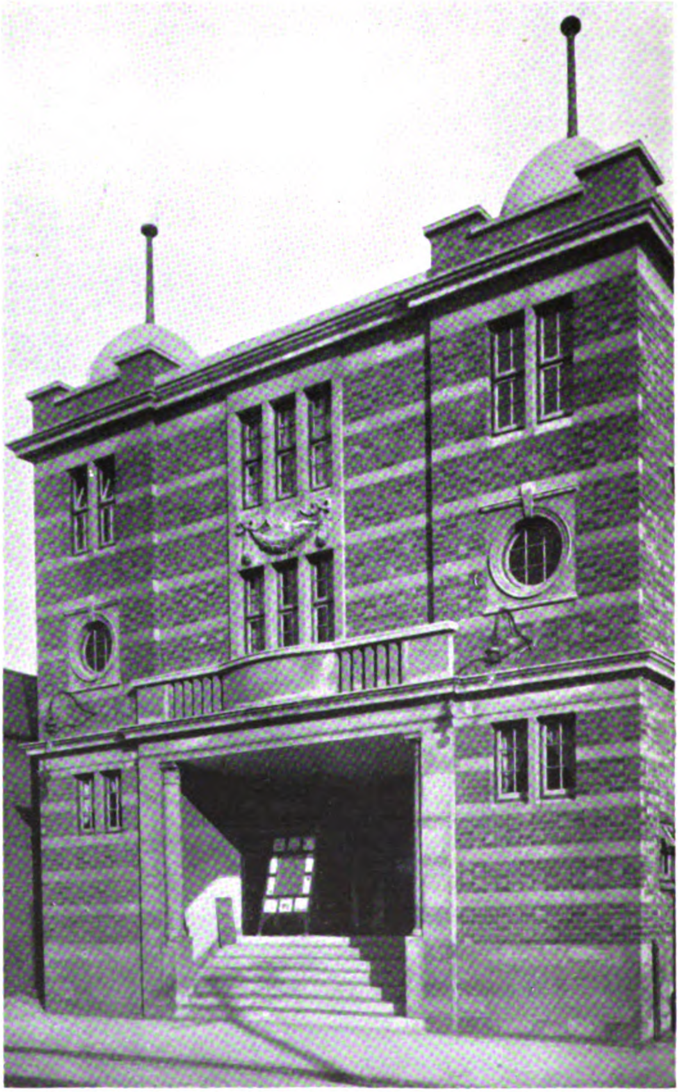
Just as the stone block influenced the architecture of the Egyptians and the brick arch that of the Romans, so have building materials influenced the architecture of every era. A hint of the coming power of reinforced concrete is visible in the art of building to-day, but it is only when it has definitely made its mark on our architecture that the age of reinforced concrete can truly be said to have begun.

One of the early examples of good reinforced concrete buildings in England is found in the Cornwall Press Printing Works in Stamford Street, London, which was built in 1909 to the design of Mr. G. F. Collinson, F.R.I.B.A. This building stands after fifteen years as a fine example of architecture suitable to reinforced concrete, and a record of the weathering properties of concrete in London atmosphere. As instances of strictly utilitarian buildings of the war period we find factories built by the B.S.A. Company, the General Electric Company, and Messrs. Vickers, Ltd. In more recent years we see the beginning of an endeavour to produce a pleasing building in reinforced concrete without extraneous embellishments. In the Fortune Theatre, which was recently opened in London, a specially-selected aggregate in the concrete was exposed by means of a pneumatic hammer—an experiment which I hope will lead to further developments.

It is not only in the field of large buildings that reinforced concrete has achieved success, but it has proved itself a most efficient material for water towers, silos, bunkers, and bridges, of which we have some outstanding examples. In fact, very few buildings are now erected without reinforced concrete in some form or other, either in floors, staircases, or retaining walls.

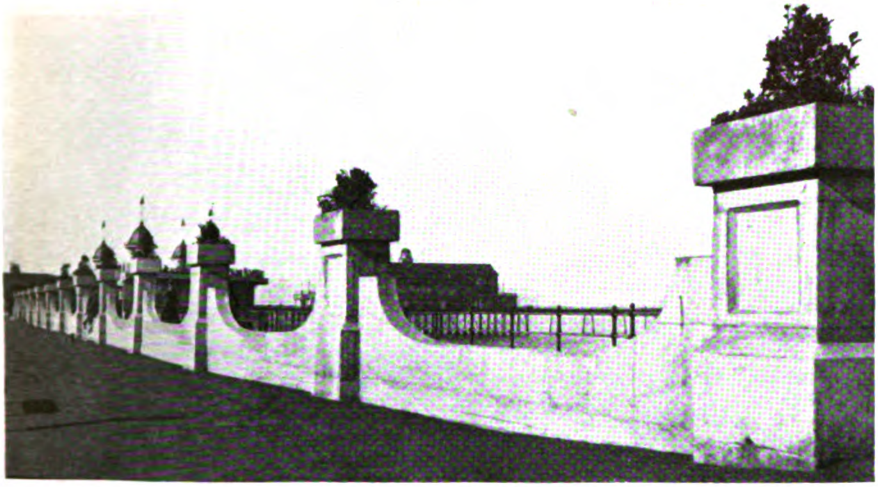
Speed of Erection.

There is always a controversy going on as to the relative speeds of construction in steel and concrete, and the general impression appears to be that concrete is slower than the steel frame, but this difference is, I think, more apparent than real. If the time is calculated from the passing of the final drawings to the completion of the building there is little between them. The concrete building can make considerable headway during the time taken to



[*Mr. J. A. West, Architect.*

Cinema at Ilkestone, with Cast-Stone Dressings.



Dwarf Wall at Herne Bay: Concrete poured into Steel Moulds.

fabricate the steelwork. When the steel erection is started, however, very rapid progress appears to be made, but it should be remembered that this steelwork ought to be encased in concrete or brickwork to compare with reinforced concrete, and when this is taken into consideration the balance in time should rest, if anything, with concrete.

Surface Treatment.

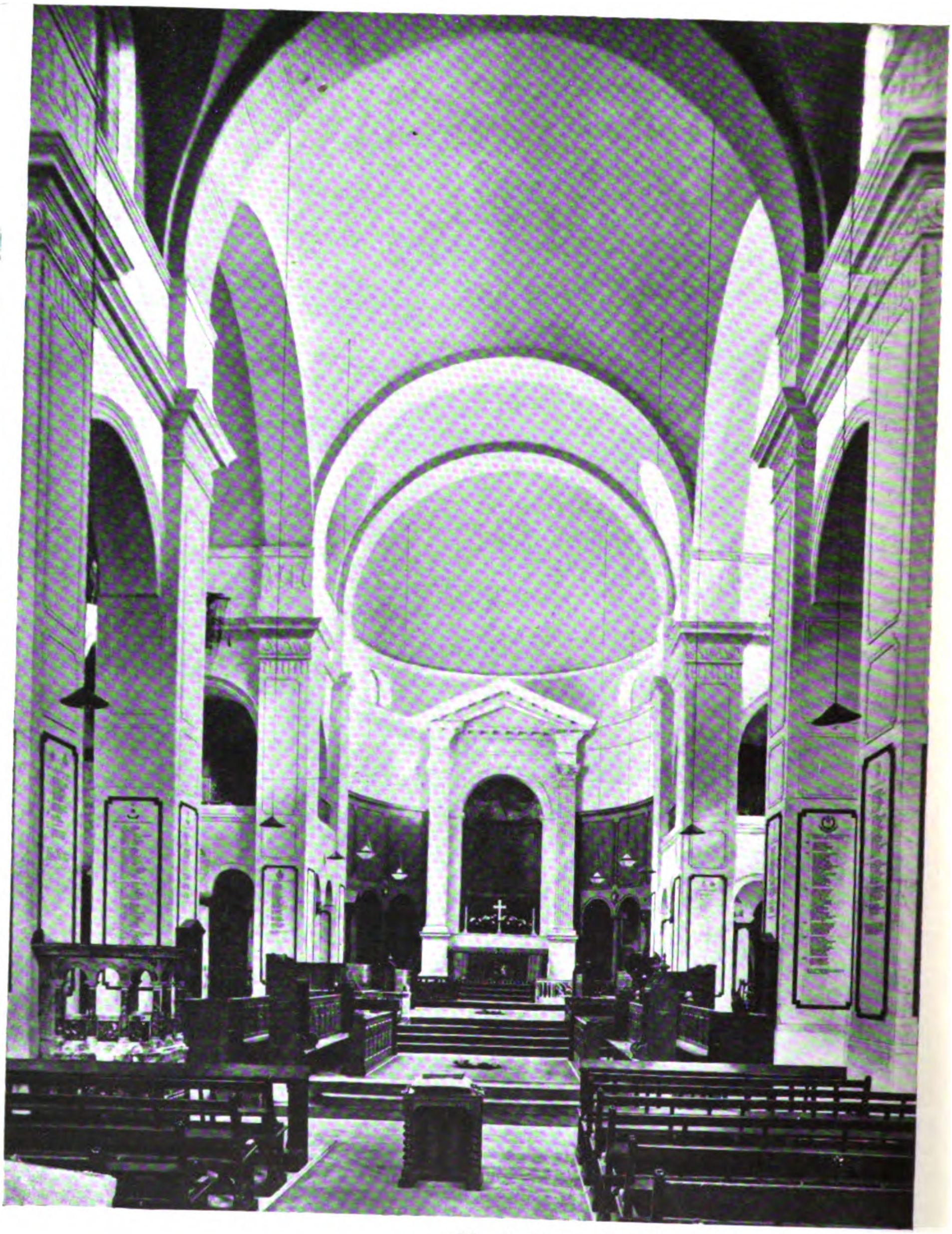
From the architectural point of view reinforced concrete compared with stone or brickwork as a building material is at a considerable disadvantage, as its texture is usually unpleasing and requires additional expenditure to render it acceptable to the artistic eye. Herein lies a very wide field for future research, and it is almost certain that the satisfactory solution of this problem will have far-reaching effects upon the prosperity of the industry.

"A Great Future."

What, now, of the future? Reinforced concrete is no longer experimental. Sufficient work has already been done to prove its permanence and suitability, as well as the soundness of modern practice. Many improvements can and will be made both to the quality of the concrete and its texture: new and quicker methods of false-work will be devised. Undoubtedly reinforced concrete has a great future, and should attain with this nation the important position that it has already reached in other countries, but I should like here to make an appeal to the Powers That Be:

A Freer Hand Wanted.

Please do not fetter it with too many rules and regulations. The industry is still in its youth, and for healthy development needs freedom and scope. It is impossible to believe we have reached the limit of our knowledge in this or any other subject. It would be most unwise, therefore, to attempt to legislate to-day for conditions which may exist to-morrow. If the authorities must have By-laws, at any rate let them give their successors power to modify them from time to time to meet improved methods or special conditions without having recourse to the present cumbersome process which is now the only method of procedure.



[*Mr. Arthur C. Martin, F.R.I.B.A., Architect.*

Sandhurst War Memorial Chapel.

(*In Reinforced Concrete.*)

Concrete Economies.

By GEORGE M. BURT.

(Director, John Mowlem & Co., Ltd.)

CONCRETE is one of the oldest of building materials. Reinforced concrete is one of the few contributions modern science has made to the age-old art of building. Ferro-concrete is concrete's eldest son—or perhaps more properly, its eldest daughter, for there are few more fascinating branches of practical science. It has simplified some and cheapened many of the engineering problems of the architect; yet it is still the Cinderella of building materials, generally used when there is

[*Mr. Wm. Higginson, Architect.*

Reinforced Concrete Warehouse at Brooklyn.

no easy alternative or as an economy to help to pay for the finery of more expensive sisters.

Improvement in Portland Cement.

The history of Portland cement during the past twenty years is distinctly progressive; both its efficiency and its reliability have been more than doubled, and there is always a ready supply. But, despite this progress, specifications remain much as they were in the earlier days of concrete. A larger proportion of cement is often used with the idea of hastening the setting of concrete, but the chemists of the cement world have made this wasteful procedure unnecessary now rapid-hardening Portland cements are available. If full advantage were taken of the improved quality of modern Portland cement, considerable savings would be effected by the use of leaner mixes.

Speed of Construction.

In English practice real speed is apparently of little account; it is sometimes asked for, seldom paid for, and almost universally ignored in design and execution; whereas in America the contractors are encouraged to use every means in their power to expedite building construction. It almost seems that the advance in modern materials and the ingenuity of design of modern mechanical accessories are wasted, or at any rate not sufficiently appreciated.

Costs.

It may be appropriate to call to mind that at the present time there is a great shortage of bricklayers, and as a consequence the output from those who are available is abnormally low. On a wall 18 in. thick the skilled labour on a yard cube of concrete is about half of that required for a yard cube of brickwork, and the unskilled labour is approximately as 3 is to 2. Yet how often is concrete substituted for brickwork? The lack of appreciation of the labour-saving possibilities of concrete tends to make the building industry an increasingly sheltered trade. The industry needs competitive methods both in the matter of design and execution, and concrete is the first to hand and also the surest alternative material by which cost may be reduced and construction speeded up.

It is fashionable at the present time to talk about restriction of output and to blame the contractor and the operative for high costs. Whether this be so or not, there has been no increase in cost so far as concrete is concerned. Improved methods of destruction and construction have resulted in the labour cost of concrete work being almost the same as before the war, in spite of wages being more than double, whereas with brickwork labour costs are more than double and bricks still cost about 150 per cent. more than in 1914. It is difficult to see how this state of affairs can be improved upon for very many years to come. It would seem that the only hope of reducing the cost of building and increasing the speed of erection is to increase the use of concrete by more elasticity of design, and decrease the cost of that concrete by taking advantage of the improved quality and rate of hardening of present-day cement. Concrete is the only material which at present seems to give opportunities for ingenuity in design and extended use of machinery.

Concrete Architecture.

It may safely be said that architects have not yet properly realised the claim of concrete for other uses than floors and foundations. Modern architecture invariably "demands" brickwork, and only occasionally "permits" concrete. This will probably continue until a style of architecture suitable for concrete is evolved, and there are signs that a definite move is now being made in this direction; the fact that some of the leading architects are beginning to take an interest in the material is encouraging, and I believe the subject of reinforced concrete design will shortly be taken up by the architectural schools. A recent remark of the art critic of *The Times* seems to point hopefully; he says, "Concrete, though shaped in the mould, retains a certain capacity for getting round curves and corners which is not possessed by stone." A perfectly sound admission, previsioning a great possibility, but how far will it influence the professional mind?

Reinforced Concrete in Marine Structures.

By C. J. JACKAMAN, A.M.Inst.C.E.
(Managing Director, A. Jackaman and Son, Ltd.)

Early Prejudices.

Looking back over a period of twenty-one years, when it may be said reinforced concrete was in its infancy in this country, one is well able to appreciate the improvements which experience and skill have introduced, not only in design, but in the execution of this form of construction. Much prejudice, or perhaps it would be fairer to say excessive caution, prevented some engineers adopting it, added to which the first cost in many cases was a contributory reason for discarding its use in favour of the older systems of timber or iron. In coming to this decision it may be presumed that the perpetual cost of maintenance and decay of structures built of timber or iron was forgotten and the corresponding saving effected by using reinforced concrete overlooked, as also was the immunity of risk and loss from fire.

Jetty at Royal Victoria Dock : Just Completed.

Economy and Strength of Modern Piles.

Speaking more particularly of jetty work, it will be remembered that in the early days piles were moulded vertically and consequently their cost rendered their use, except in some special cases, almost prohibitive.

To-day, however, precast piles are moulded horizontally, with great advantage in cost, and they are frequently being made from fourteen to eighteen inches square and of considerable length, at a cost below that of corresponding piles of pitch pine, whilst their supporting power greatly exceeds that of timber, and they have the further advantage of being capable of being driven to a severer test than timber could reasonably be expected to sustain.

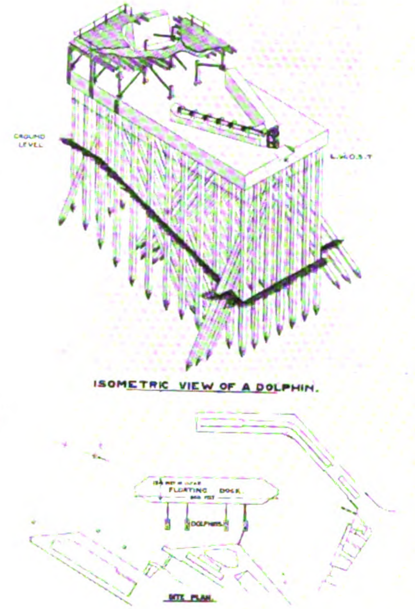
Amongst other advantages reinforced concrete piles offer in salt water is the freedom from the ravages of the *Teredo Navalis*, whilst from a constructional point of view the greater rigidity resulting from the monolithic attachments to them of the bracing and decking members puts reinforced concrete in a pre-eminent position for pier and jetty construction. In this connection I particularly welcome the growing practice of making the main reinforcement of the piles in such structures continuous right up to the deck wherever possible; it is a detail of the value of which I am strongly convinced from practical observation, and one which I have urged on many engineer friends.

Improved Methods and Materials.

It was the practice some years ago to use flat bar stirrups for the shear members in the decking of jetties, floors of warehouses, etc., and this was always a source of anxiety to those responsible for the execution of the work. In modern designs these happily have disappeared, and are replaced by round bars securely and correctly fixed in direct contact with the main reinforcing rods.

Rapid Construction.

Amongst the lessons we in the concrete industry have learnt from past failures I would give special prominence first to the value, now almost generally recognised, of correctly grading and proportioning the



Dolphin for 60,000-ton Floating Dock at Southampton.

materials; and second of allowing an increase in the external thickness of the concrete cover to the reinforcement above that formerly considered sufficient. The former has been amply demonstrated in the research work carried out in recent years, and is, perhaps, nowhere of greater practical benefit that in marine structures, while the latter point proves of such inestimable advantage to the structure as to justify its relatively small additional cost in all cases.

Any review, however brief, of the growth of reinforced concrete would be incomplete without a reference to the greater perfection now attainable in the uniformity of the concrete resulting from the use of mechanical mixers, which give absolute regulation of the water content, a factor whose importance can scarcely be overestimated. By these means a concrete is easily produced of great density which will give a crushing strength of well over 4,000 lbs. per square inch at twenty-eight days with an absorption almost negligible.

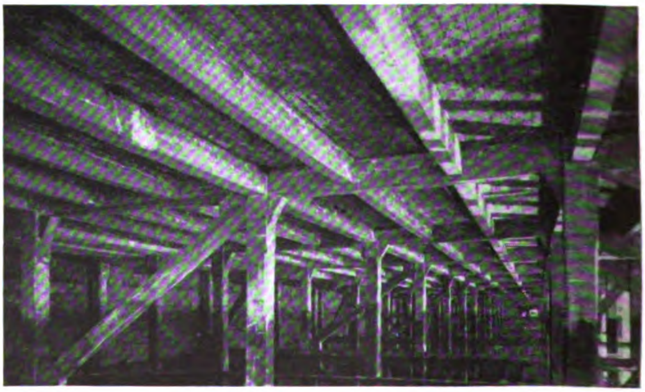
By the recent introduction of rapid-hardening Portland cement compression tests as high as 5,400 lbs. per square inch have been obtained in seven days, and piles made from this cement have been successfully driven seven days, and in a few cases four days, after they have been cast, without any evidence of fracture, whilst it is on record that bridges where aluminous cement has been used in the superstructure have been opened for traffic forty-eight hours after completion.

Evidence of the impermeability of concrete is afforded by the numerous examples of water towers, reservoirs, and even wine storage tanks which have been constructed.

The Future.

If the progress made in the past is an indication of what may be accomplished in the future, then we may reasonably hope to see this system of construction generally adopted in jetties, wharves, piers, etc., where the capacity to support heavy stationary and moving loads, such as cranes, locomotives, etc., is of first consideration.

[*** The Dolphin at Southampton, the jetty at the Royal Victoria Dock, and Parkeston Quay were carried out by Messrs. A. Jackaman and Son.—Ed.]



Parkeston Quay, Harwich : View under Decking.

Concrete for Houses: Economy and Suitability.

By CHARLES BOOT.

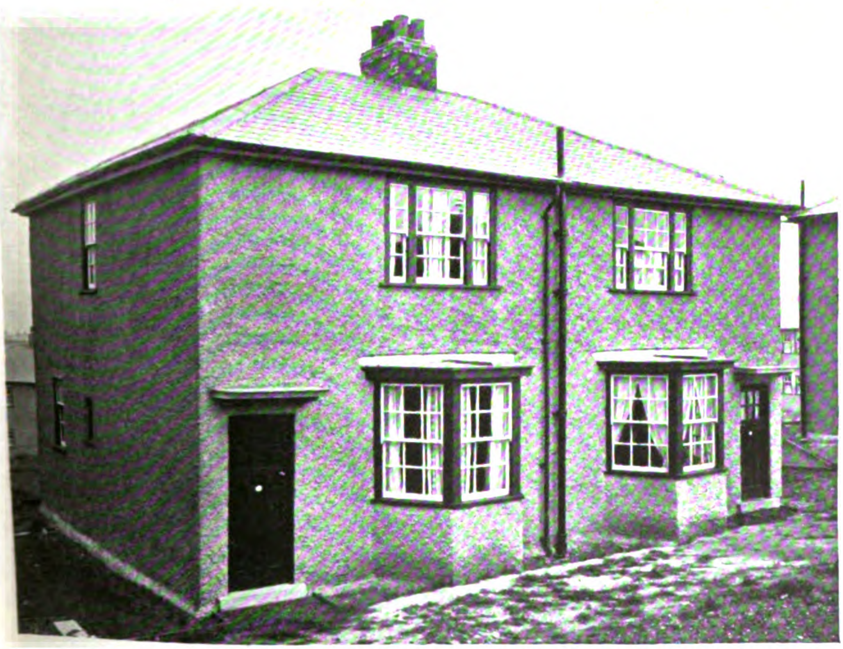
(Chairman, Henry Boot & Sons (London), Ltd.)

THE shortage of skilled labour in certain of the key industries concerned in building has brought concrete into greatly extended use for house construction during the past few years, and we are approaching the "Concrete Age" much more rapidly than would have been the case had not dire necessity compelled our architects, engineers, and housing experts to supplement their building schemes by an intensive use of this method of building.

Official Approval.

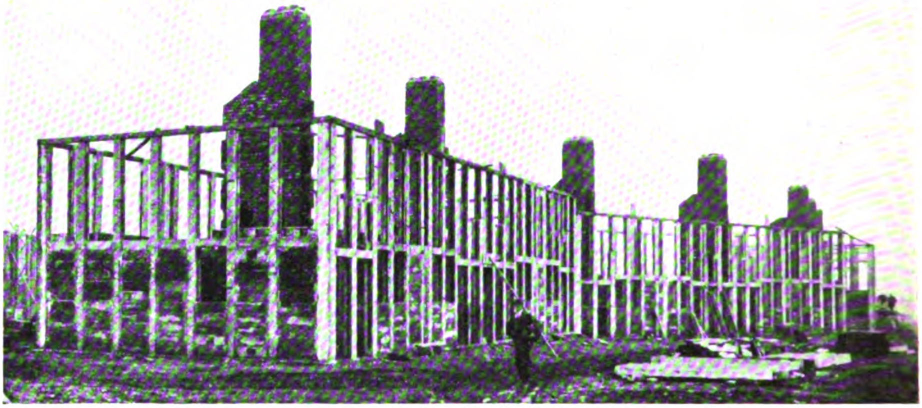
Only during the past year has concrete housing received a really unqualified welcome from the authorities, first in the report of the Committee on New Methods of House Construction, issued in January, 1925, in which it is stated: "Concrete is entirely reliable. . . . This method of construction promises more houses and more permanent structures than any other alternative . . . with the least call on the skilled building operatives. . . . The maintenance costs of such houses will compare favourably with those of any other."

Again, in a recent speech before the Institution of Structural Engineers in Birmingham, Sir Charles Ruthen, the Director-General of Housing, said "the only new method of house building that will last and survive all criticism."



[*Mr. F. E. P. Edwards, F.R.I.B.A., Architect.*

A Pair of Houses Built on the "Pier-and-Panel" System.



" Pier-and-Panel " Houses during Construction.

Concrete Houses Fifty Years Old.

The use of concrete for the building of houses is not new. An old Scottish builder wrote recently inviting me to inspect 200 concrete houses which he built over fifty years ago in his native town. I did so, and found that they were entirely satisfactory in every way, whilst brick houses near by, built in the same period, were dilapidated and almost unfit for occupation, the bricks being in an advanced stage of decay and the interiors damp, in spite of constant repairs, whilst the concrete walls had not cost a penny in maintenance in fifty years.

Economy of " Leaner " Concrete.

The comparative cost of house building in concrete and brick has until recently usually been too much in favour of the latter to make it possible to produce an efficient concrete house within the limits of cost prescribed for " housing for the working classes," but now Portland cement is of such high efficiency as to make the use of cheap aggregates practicable in a ratio of mixture which would have been impossible a few years ago. Further, where our forebears demanded not only a " rich " mixture but also one perfectly voidless, we now find that housing experts are satisfied that light aggregates and ratios up to 10 to 1 are perfectly satisfactory. One Continental system uses a large aggregate the size of billiard balls, and houses erected with walls, floors, and roofs in this material have proved to be substantial, dry, and permanent.

Maintenance Costs.

But, as in the building of brick houses the " jerry builder " has sometimes degraded a method of construction which is otherwise recognised as one of the best, and in which beautiful examples of the builder's art exist in every part of the country, so also many instances of the " jerry building " of concrete houses has brought that method a measure of disrepute ; whereas concrete building of proper design and construction is the most permanent of any known method.

In some of the earlier erections of post-war concrete houses, where the particular peculiarities of local aggregates have not been sufficiently tested before use, and possibly reinforcement, if used at all, has been a matter of " rule-of-thumb," there have inevitably appeared some expansion cracks as the fabrics have matured ; in one such instance local opinion has recently been greatly perturbed upon a report of their Borough Engineer that, although the interiors of their concrete houses are perfectly satisfactory, the exteriors require £5 per house spending upon them to make them permanently sound. This statement is broadcast and carefully noted by those prejudiced against concrete, who fail to realise how relatively small such an expenditure is compared with a cost of probably double this amount every few years for painting steel houses or re-pointing brick houses.

Surface Treatment.

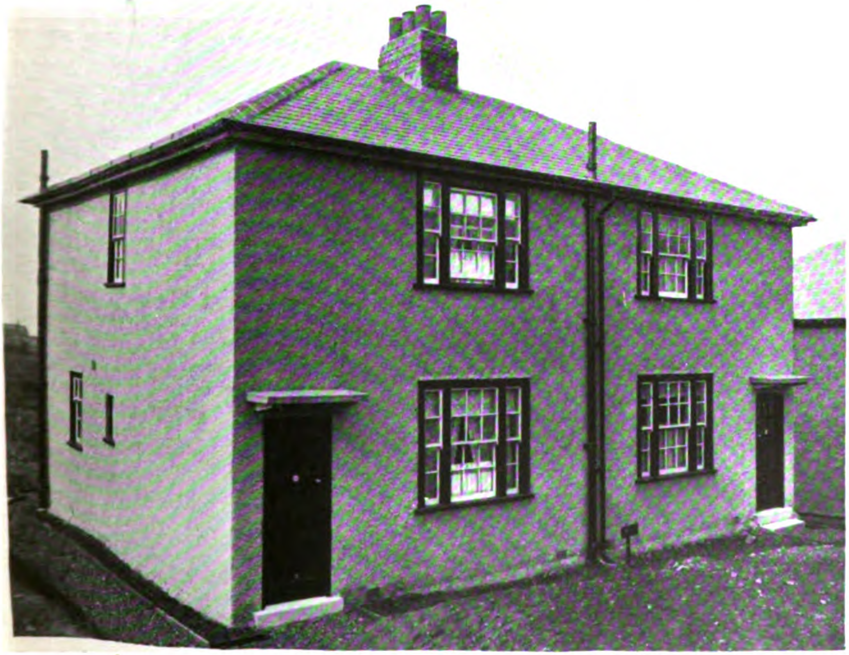
These slight defects are frequently the concomitant of the demand for cheapness, but a single repair usually makes the houses permanently good and stable. It also gives the opportunity of a slight change in colour of texture in the finished coat, although general approval is expressed for the delightful grey tint acquired on maturity by the natural concrete.

Very pleasing variety may be obtained in the finished tints by the use of varying methods of "roughcast"—a "dry" roughcast may be gravel, crushed flint, broken spar, or one of many other readily available local materials, or a "wet" roughcast may be varied in texture by various devices known to the plasterer-craftsman. Careful selection of the colours of paint on the woodwork of doors and windows, in harmony with these varying tints of roughcast, will also greatly relieve the monotony of colour on a large scheme without any addition to the cost—deep browns and greens being the favoured colours to harmonise with the warm tints of gravel or the grey of cement. Modern town planning also effectively prevents any monotony by the avoidance of straight rows of houses and the provision of ample open spaces.

A great advantage of concrete construction for houses is that a minimum of skilled labour is required, the preparation of the component parts and the erection thereof being mainly done by unskilled labour, and large building schemes will therefore find occupation for large numbers of men now unemployed.

Modern Methods.

The method used by my firm for many thousands of concrete houses is the pre-cast "pier-and-panel" system, which consists of the casting in moulds of hollow columns the full height of the house; these are then erected at intervals of about a yard, the panels being filled in with slabs, pre-cast in a "Winget" pressure machine. The piers are fitted into sockets in the foundations, and a reinforced concrete wall-plate is fixed *in situ* around the entire house at the eaves; further steel reinforcement at the first-floor level



[*Mr. F. E. P. Edwards, F.R.I.B.A., Architect.*

"Pier-and-Panel" Houses at Sheffield.

makes the whole erection perfectly monolithic. The slabs forming the panels have a tapered groove at each end, which fits into tongues cast on the piers. These tongues are omitted at intervals, the slabs being placed in the voids and thence lowered to their permanent bed. The whole fabric is thus fitted together like a Meccano toy. This method has endured every test.

Speed of Erection.

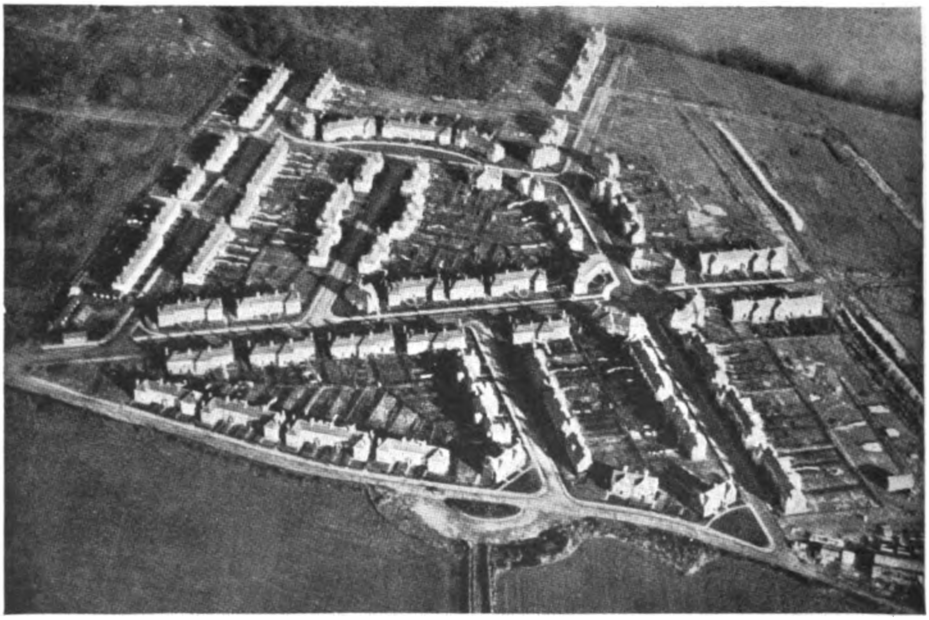
There should be no limit to the output of houses in this form of construction. Unlimited supplies of aggregates being available, and the country's capacity for the production of cement being ample, it only remains to organise the casting and erection at any desired speed. To produce 1,000 houses on any given site it is merely necessary to cast all the component parts for twenty houses every week, and this may be multiplied indefinitely. The other trades can be organised in the same manner. Indeed, the only limiting factor is the provision of money to finance such extensive schemes. To meet this the most practical way is, in my opinion, a scheme of easy terms of purchase for tenant-owners.

Concrete walls built in this manner are practically indestructible. They will resist the most severe climatic conditions, they are fire-proof, and there is no necessity for frequent re-pointing as in the case of brickwork, so that the cost of maintenance, so far as the fabric is concerned, is practically nil. The loss of heat from a warm room through the wall to the cold outside air is less than in the case of solid brick or stone walls, and similarly the heat of summer does not so readily affect the coolness of the room.

Materials.

Suitable aggregates for concrete are available in most parts of the country, and in some districts there are enormous dumps of clinker available for concrete-making near big works and power stations. Efficient modern methods of stoking the boiler furnaces of these plants produce an aggregate which is entirely free from particles of coal, and is everything that can be desired for concrete house construction.

My advice to housing authorities is to build all the concrete houses possible, thus using waste materials and surplus labour, and to avoid any form of building.



[*Mr. H. E. Farmer, F.R.I.B.A., Architect.*

Concrete Houses (Pier-and-Panel System) at Bulwarks, Mon.

Cappelen Memorial Bridge, Minneapolis.
(*Longest Reinforced Concrete Span* (400 *ft.*) *in America.*)

such as steel construction, which would only last a few years and would rapidly degenerate into a rusty and insanitary slum.

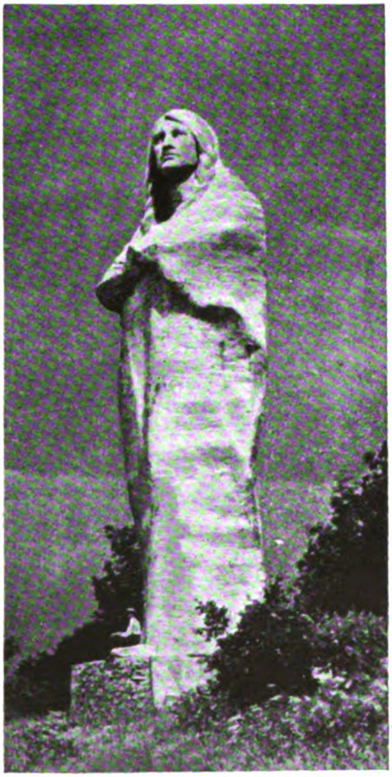
Craftsmanship.

The art of the architect and the skill of the building craftsman have hitherto been consistently directed throughout the ages to the designing and shaping of their work in such a manner as to secure the utmost beauty and permanence. They have used the marvellous materials which Nature and the wit of man have provided in limitless abundance, and have formed these into structures which have endured the test of centuries of storm and tempest. There is no man worthy of his craft but would scorn to build with other than these, and we have still the same materials available in the same abounding measure.

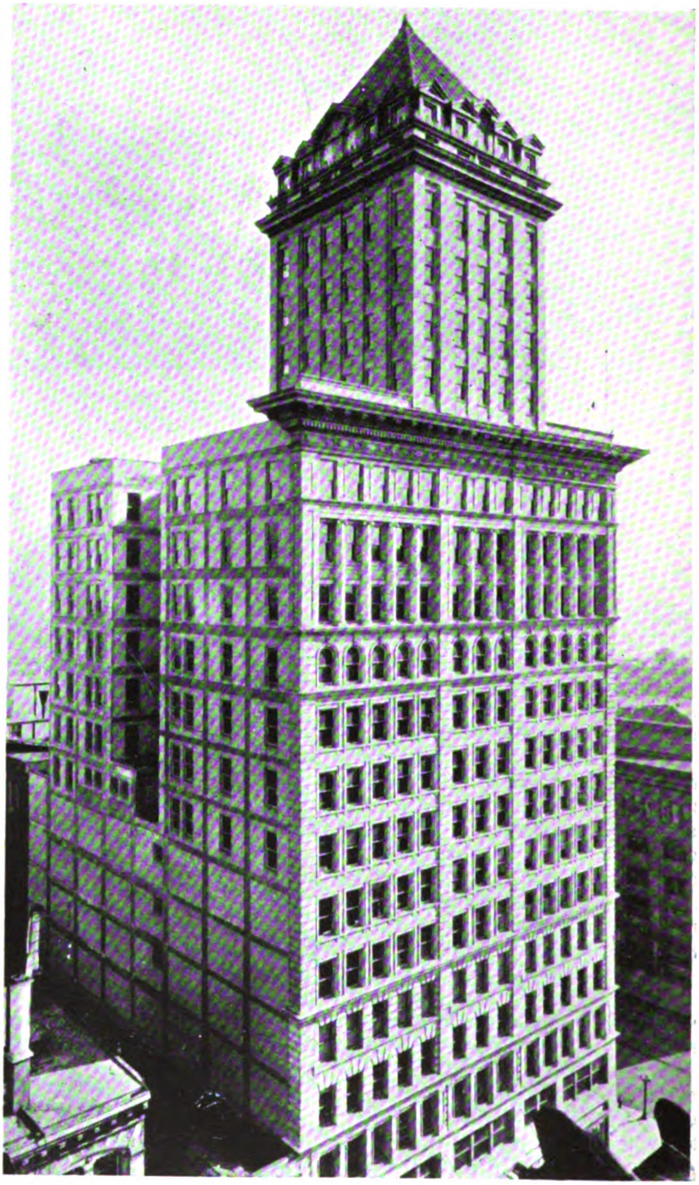
Permanence.

Concrete house building has now secured a permanent hold, and will increase in favour as the undoubted advantages of modern methods become more generally known. It is already a significant fact that on sites where the building of both brick and concrete houses is proceeding tenants and purchasers now invariably prefer the concrete house.

Finally, I may say that I am quite content to stake my reputation as a building craftsman upon the efficiency and permanence of a properly conceived system of concrete housing; I have already built some thousands of these houses, and have thousands more in the course of construction. They will, without doubt, outlast houses built in any other method.



[*Mr. Lorado Taft, Sculptor.*
Memorial in Concrete to an American Indian.



United Brethren Building, Dayton, Ohio.

(Reinforced Concrete Frame and Floors : 22 Stories High.)

Twenty-one Years' Progress in the Portland Cement Industry.

By A. C. DAVIS, M.Inst.C.E.I., M.I.Mech.E., F.C.S.
(*Works Managing Director, Associated Portland Cement Manufacturers, Limited.*)

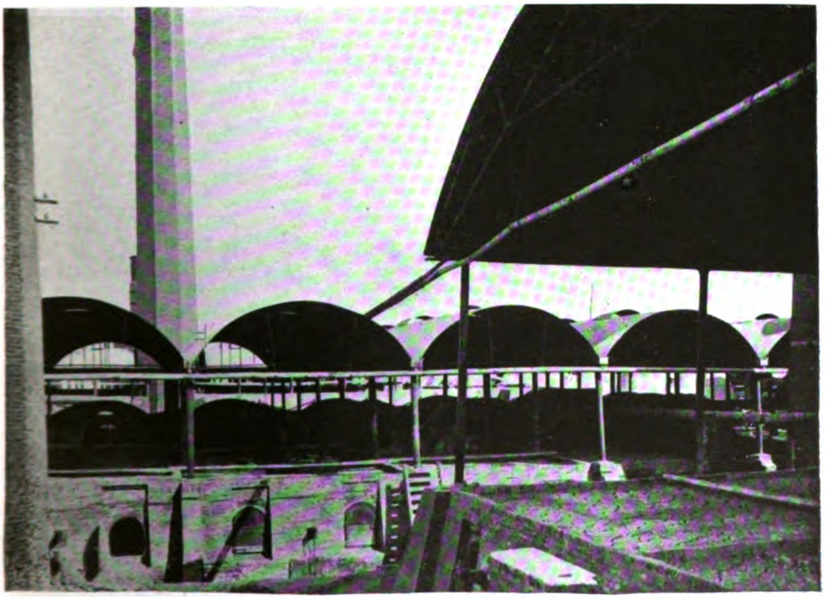
Of the now one-hundred-and-two years that Portland cement has held its sway—since its name was originally invented in 1824—the period of the last twenty-one years has been accountable for far more progress and development in the manufacture, quality, and uses of Portland cement than all the preceding eighty years.

Invented, patented, and first produced on the Thames—and to-day without a rival—Portland cement still pours out from the very factory which actually, in 1822, made "British cement," and this works continues to produce its substantial quota of some 7,500 tons of Portland cement a week of the country's output, and is, moreover, the largest factory to-day in the United Kingdom. All day and every day the hazy vapours of Swanscombe cement kilns are seen to rise from the busy works; while at night with its myriads of lights, the sullen glow of the century-old works, is like the watchful eye of some brooding spirit over the younger generation surrounding.

Progress in Manufacture.

Although Portland cement manufacture has continued uninterruptedly for a century in the district of the Thames, and has now spread elsewhere, there are still enormous raw material deposits all over the United Kingdom admirably adapted for the production each year of many millions of tons more of Portland cement, while the increasingly large number of uses to which modern Portland cement may be applied must be attributed to the great strides which have been made during recent years in the science of the manufacture of this product.

Of the progress in manufacturing technicalities, a review covering the period mentioned can, perhaps, be brief, as its interest lies with few perhaps of my



A Battery of Old Chamber Kilns.

readers. But of such factory improvements it may be mentioned that the plant for manufacturing processes has developed in line with the improvement in quality. For instance, the increasing use of mechanical excavators for the raw materials, as outputs have increased, has been inevitable, while the more constant and regular composition of the mixture of raw materials due to an improved chemical and mechanical control in all stages of the manufacture is a very prominent feature to-day as compared with the empirical practice of years ago.

In 1905 the old bottle, chamber, and shaft kilns for burning were giving way to small 60 ft. by 6 ft. rotary kilns with an output of one ton an hour, and these have since been replaced by rotary kilns 250 ft. long by 11 ft. diameter with a capacity of 15 tons an hour.

The high labour and fuel charges and inferior quality output of intermittent kilns have given place to low fuel costs and less labour, with much increased outputs of a superior and more regularly calcined product from rotary kilns, thus helping to a large extent the raising of the standard to the cements of to-day.

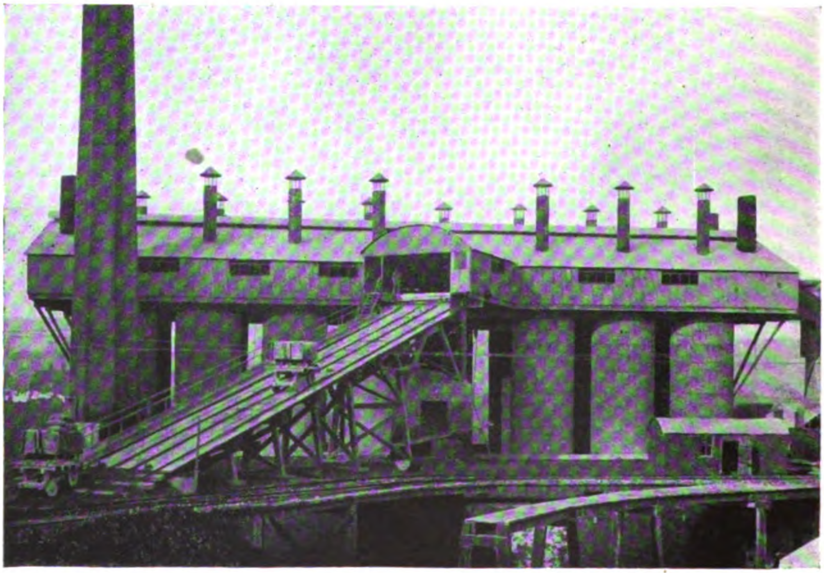
The clinker grinding plants of old, in the shape of millstones and edge runners, were also giving way twenty-one years ago to the two-unit ball and tube mills, substituted to-day by the single-unit combined mill, while the old flint pebbles then used as a grinding medium now simply form a useful aggregate for the concrete foundations of new mills where steel grinding bodies have taken their place.

Silos for cement storage, and the mechanical packing into sacks and casks, have appeared during the past decade, while power generation for the whole of the factory plant generally has seen the passing of slow-speed steam engines and gas engine plants in favour of turbo-generators and electric power.

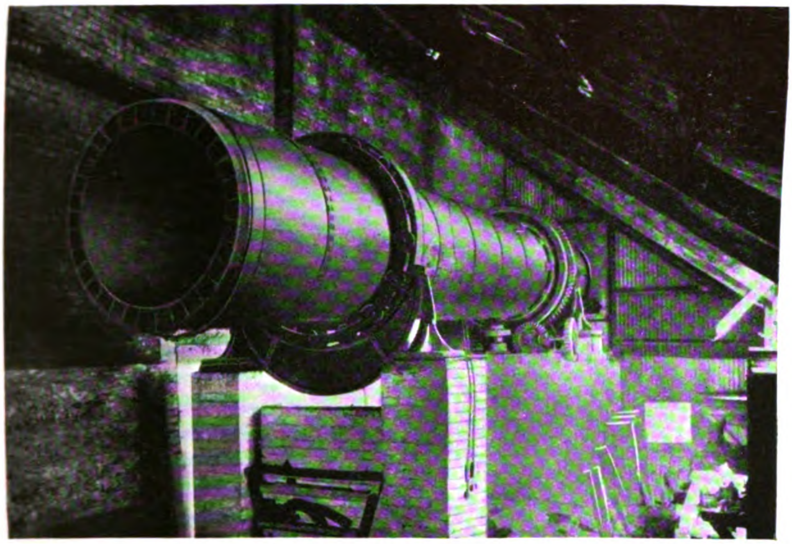
Workers.

No less important is the progress in the workers' position in the industry to-day as compared with years ago. There is now a clear aiming at co-operation, with a genuine desire on the part both of employer and employed to bring about better conditions in the industry. Opposition to trade unionism has gone, and a system of collective bargaining by joint judgment and agreement now prevails.

Similarly, labour rates have advanced substantially, and working conditions have generally improved. There is no



A Block of Shaft Kilns.



One of the First Kilns (1887) Rotary.

lost time to-day, and a free weeks' holiday is given. The twelve-hour shifts have been replaced by an eight-hour day, and overtime rates not previously heard of in the industry are now generally adopted. There is also a distinct advance in welfare conditions, and the industry is still striving for even further improvements in the interests of its workers. There is a definite policy of co-operation between employers and employed, and it can be said with truth that 'peace prevails' in the cement industry. May it continue!

Improvements in Quality.

But the past twenty-one years of Portland cement manufacture have indeed witnessed a revolutionary improvement in the quality of genuine Portland cement. In 1905 the output of the country approached two million tons per annum—to-day it is four millions. Finely-ground cements were then regarded as doubtful, and tests for fineness did not go beyond the sieves of 50 and 76 meshes per linear inch. To-day the fineness of cement is such that it can only be gauged by tests on a sieve of 180 meshes per linear inch, while the importance of fineness in determining quality is properly appreciated.

The tests for tensile and crushing strengths of Portland cement in 1904 were substantially satisfied with what are to-day considered to be low results, and such tests can easily be doubled by Portland cement of the present time.

The advent of a British Standard Specification just over twenty-one years ago, as well as the development of higher technical research in manufacture, have had much to do with this satisfactory condition of affairs, while it can now be said with emphasis that the present-day exceptional quality of Portland cement has never before been attained in the history of its manufacture.

The value of Portland cement is hardly recognised as widely as it should be. Its durability far exceeds that of bricks and building stones, while the extraordinary architectural, and more especially engineering, feats of the past decade presage still further important developments in concrete construction in the future, because the advance in the manufacture and qualities of Portland cement are being specifically devoted to the rapid constructional work which is necessary to-day, and will be more in demand in the future.

The results of these recent improvements in manufacture are that modern Portland cement as compared with the product of even a few years ago is distinguished mainly by its much higher results in tensile and crushing strains, absolute freedom from unsoundness, a substantial increase in fineness, and ultimately in sand-carrying capacity, and the ability to ensure more satisfactory concrete results with a smaller proportion of cement to aggregate. Coupled with these main features, the rapid-hardening qualities of the Portland cement which is made to-day were never dreamed of twenty-one years back.

Foreign Competition.

In writing upon the progress in Portland cement manufacture during the past two decades it is well to look, first of all, at the picture of twenty-one years ago. In those days the writer happened, through the good fortune of spare time and enthusiasm, to have written a book upon the manufacture of Portland cement as it then occurred. Here it is on record that in 1904 the British Portland cement industry was suffering under that process of "peaceful penetration" of trade by Germany, which most countries of the world then found to be so persistent and so insidious. Cheap foreign labour and cheap coal, together with subsidised freights, no standard of quality, and free imports, found the period of manufacture of British Portland cement twenty-one years ago one of a German invasion of the British cement market. The price of the foreign cement was one the British manufacturer was reluctant, if able, to sell at, and consequently large home contracts were secured by our foreign rivals.

At that time, also, the British cement manufacturer laboured under the necessity at home of working to the most divergent, multifarious, and fastidious specifications. Of the making of specifications in England there was no end. Instead of cement being manufactured and tested according to lines thoroughly well settled, it was subjected to endless variations in qualities which were demanded by more or less experienced officials. What was then termed the British cement manufacturers' "conservatism and independence" was really the not very unnatural desire to point out that the compositions and strengths and setting times specified in a cement by the variety of opinions which then existed would not be likely to yield the results anticipated. The manufacturers often supplied their usual brand of cement, which was, in many cases, superior in quality to that asked for by unscientific specifications, and thus perhaps differed from many other specifications both in composition, fineness, and tensile strength.

Modern Plant.

All this has, however, been altered, for late in the year of 1904 the first issue of the British Standard Specification for Portland Cement was published — an innovation welcomed alike by both the manufacturer and consumer. The standardisation of quality in this country meant a drop in the importation of foreign and inferior brands of cement, and from this time onwards the British manufacturer forged ahead, both in manufacture and quality, as a result of being able to concentrate his efforts on the operation of his plant for the uniform production of the grade of cement required by the Standard Specification at a minimum cost to the consumer.

The steady progression in quality of British Portland cement also arose from a rapid awakening in the British industry; home manufacturers became actively engaged in re-organising old works and building modern factories, with the result to-day that for quality of product British cement is not equalled the world over.

The adoption of the rotary kiln in Portland cement manufacture and the advent and continuous improvement of high-quality cements have brought about this unique position, and the manufacture of cement in the United Kingdom is now carried on under strictly scientific and chemical control, together with the aid of machinery and plant and processes which are continually being improved year by year with the object of securing still greater perfection in the preliminary selection and mixing of the necessary raw materials, in their subsequent calcination, and in the final grinding to an impalpable powder of the clinker produced therefrom.

The results of these modern improvements are now so widely and so freely recognised on every hand that with the improved manufacture of Portland cement to-day, both in practice and theory, we have seen some of the most interesting developments in quick concrete construction brought about by the introduction of modern rapid-hardening Portland cement, and of which such examples as the British Empire Exhibition at Wembley and the urgent road construction work now proceeding in and around London may be mentioned.

Increase in Fineness and Strength.

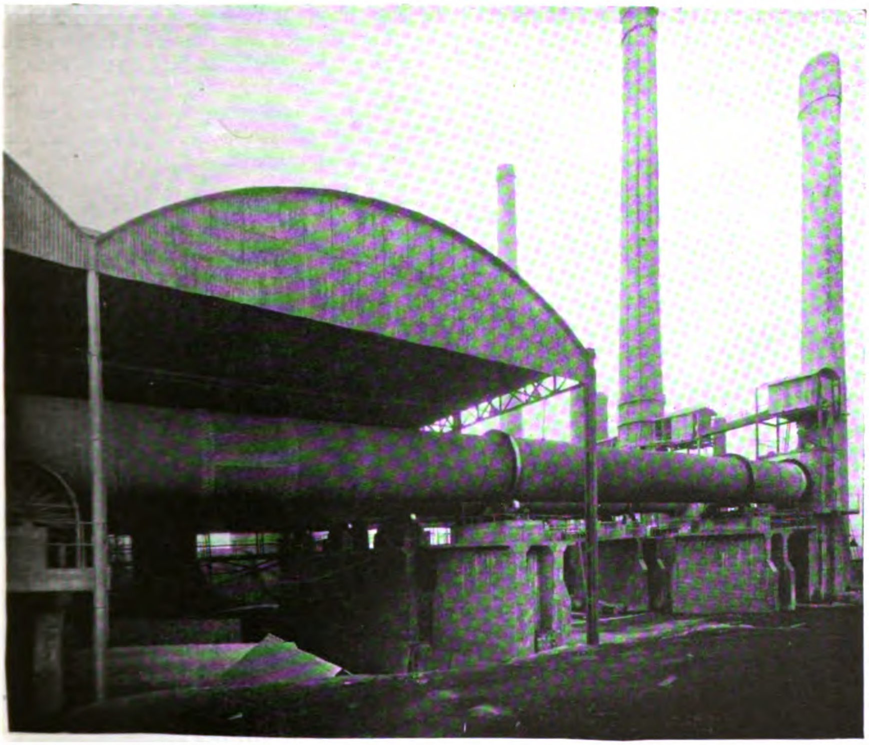
Twenty-one years does not seem long to have to go back in an industry over a hundred years old, but the vast changes in Portland cement manufacture and quality during this time can be said to be little short of extraordinary.

Twenty-one years ago the neat tensile strength of Portland cement was rudely strung up to 400 lbs. per sq. in. at 7 days, and 500 lbs. at 28 days. To-day the same strength is obtained with a mixture of 1 part of cement to 3 parts of sand at the same ages. The 7-day sand test of the British Standard Specification late in 1904 called for a minimum of 120 lbs. per sq. in., and at 28 days 225 lbs. The same strengths to-day with modern Portland cement are attained in 24 hours.

The fineness of Portland cement in 1905 was quite a suspicious feature of cement quality to many consumers, and complaints were known regarding cements at that time which were supposedly too finely ground to be used in their neat state. It was usual; when asking for a fineness at all, to call for tests on sieves having 2,500 meshes and 5,776 holes to the square inch, and residues of 2½ per cent. and 10 per cent. respectively were limited in 1905 by the Admiralty Specification for Portland cement. To-day the higher residue is rarely exceeded on a sieve having 32,400 holes to the square inch, and, as a consequence, consumers have learned to mix more sand with these finer-ground cements.

Twenty-one years ago the weight per bushel and specific gravity of cements were stringently tested. To-day these tests are waived in favour of the tests for strength and sand-carrying capacity and compression.

The soundness test of years ago by the inspection of pats of cement has been superseded by a standard caliper measurement of expansion after boiling, and the



A Modern Rotary Kiln Plant.

old aid of aerating cements to cool them before use is now altogether abandoned.

Even to-day the quality of Portland cement is substantially better than generally appears. The new British Standard Specification of 1925 calls for a maximum residue of 10 per cent. on the 180 by 180 mesh sieve, and modern cements well conform to this limit, and often give substantial reductions under it. The neat tensile strength of cement at 7 days is specified at a minimum of 600 lbs. per sq. in., while many cements to-day reach a strength of as much as 800 lbs. The abandonment of a 28-day neat test has been generally accepted, since the higher strength now reached with modern cements at early ages cannot be expected to continue for 28 days, the setting or hardening process having taken place within the early age; consequently there would be little increase of strength to be expected between 7 and 28 days with the modern high-class cements called for in the design for quick concrete construction. The specified minimum (3:1) sand test of 325 lbs. per sq. in. at 7 days (reaching 356 lbs. at 28 days) is generally exceeded to-day by a margin of at least 25 per cent. while the 10 mm. maximum caliper expansion test is generally reduced to 2 mm. expansion. So can the quality of modern cements be thus briefly described.

Rapid-Hardening Portland Cement.

But British manufacturers have gone further even than this. In the demand for rapid-hardening cements British manufacturers are still to the fore, while an ultra-rapid-hardening aluminous cement manufactured to-day enables heavy traffic to pass over the fresh concrete with which it is made within the space of twelve hours. The outstanding feature of twenty-one years' progress in Portland cement manufacture is undoubtedly the advantage of this new rapid-hardening cement, the distinguishing characteristic of which is the development in a few hours of the strength usually acquired in as many days, and a growth of strength in a few days equal to that developed by ordinary cements in a few months.

Rapid-hardening cements are in two classes, viz. Portland and aluminous.

Rapid-hardening Portland cement is a true Portland cement, and is made from exactly the same raw materials as Portland cement. Its process of manufacture is also very similar to that of Portland cement, but requires a slight alteration in chemical composition and degree of burning and grinding. It has a greater CaO content than Portland cement, which renders it necessary for great care to be exercised in the proportioning and mixing of the raw materials. The process of burning also demands more care and attention, and is more prolonged than in the case of ordinary Portland cement, and this extra burning produces a harder clinker which needs very careful handling and more power and plant, and, owing to its great hardness, entails more wear and tear in grinding.

The clinker has no cementitious properties when it leaves the kiln, and these are not developed until it is finally ground, which, in order to obtain the rapid-hardening qualities possessed by this cement, is to such a degree that the residue on the 180 sieve is the least attainable, and at the present day it has been brought to such a fineness that only 1 per cent. or 2 per cent. is left on a sieve having 32,400 holes to the sq. inch.

The following table gives the results of tensile and compression tests after six months on samples of rapid-hardening Portland cement.

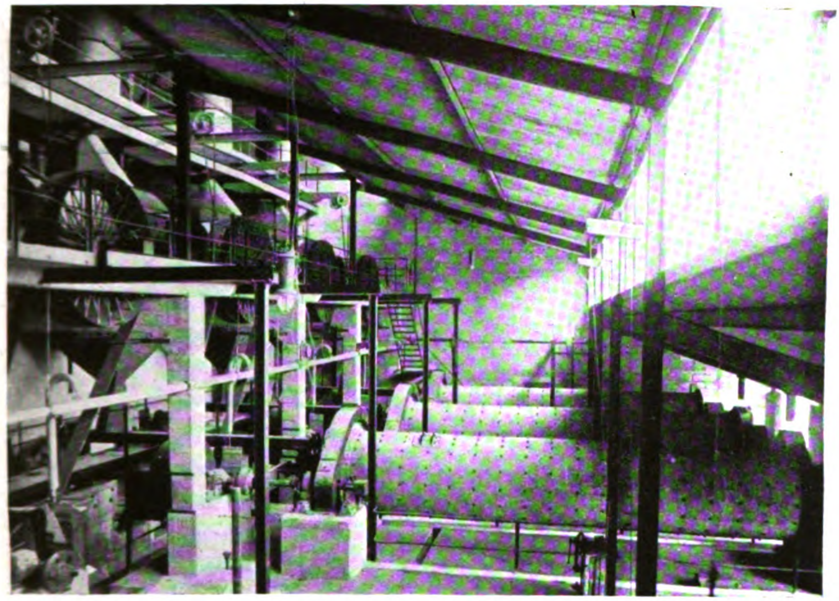
TENSILE TEST
Cement and Sand (1 : 3)

	lbs. per sq. in.
	730
	750
	790
	715
	695
	710
Mean	717 lbs.

COMPRESSION TESTS
Cement and Sand (1 : 3)

	Lbs. per sq. in.	Tons per sq. ft.
	7060	453·9
	7230	464·9
	7480	480·9
Mean Crushing Strength	7260	466·6

The following comparative table shows the great advantage in compressive strength of rapid-hardening cement over ordinary Portland cement.



A Modern Cement-Grinding Mill.

1 part Cement, 2 parts Sand, 4 parts Ballast.
Percentage of water used, 6 per cent.

	24 hrs.	2 days.	3 days.
Ordinary P.C. . .	450	1060	1890
Rapid-hardening . .	1750	2910	3853

	5 days.	7 days.	28 days.
Ordinary P.C. . .	2270	2860	4440
Rapid-hardening . .	4840	5360	6810

It will be seen from these figures that the strength of rapid-hardening Portland cement at 4 days is equal to that of ordinary Portland cement at 28 days.

When time is an important factor the rapid-hardening qualities of this cement exert their usefulness, as in the case of road construction and special surface finishes requiring to be subjected to wear at an early date. Concrete made with this cement is less liable to destruction by frost during the winter months than ordinary cement, which takes longer to reach the necessary degree of resistance. Time in removing shuttering and moulds is also saved.

Another feature of rapid-hardening cement is that it is not quick initial-setting, and thus allows ample time for mixing and placing the concrete into position before the set commences.

Aluminous Cement.

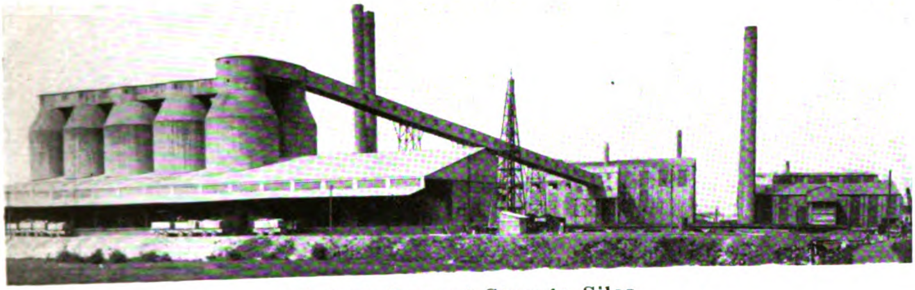
As to the alternative of "aluminous cement" made by British manufacturers to-day, this was originally discovered in France in 1908, but it was not marketed until recent years. Its chief constituent is alumina, from which it receives its name. It contains roughly 30–50 per cent. lime, 30–50 per cent. alumina, and not more than a total of 20 per cent. silica, iron oxide, and other constituents. It is very dark, almost black, and hence concrete made with aluminous cement is much darker than that made with Portland cement.

The process of manufacture consists of adding together, in definite proportions, lumps of bauxite and lime or calcium carbonate, fusing them into a molten mass by the aid of a blast furnace, cooling the fluid and then grinding the slag to an impalpable flour. Bauxite does not exist in England, and consequently this raw material has to be imported; thus the manufacturing cost is heavy.

The principal advantage claimed for aluminous cement is its rapid-hardening qualities. It attains in 24 hours, or even less, the strength obtained by Portland

TWENTY-ONE YEARS' DEVELOPMENT IN THE BRITISH STANDARD SPECIFICATION FOR PORTLAND CEMENT.

	1905.	June, 1907.	August, 1910.	March, 1915.	1920.	1925.
Fineness :—						
180 × 180 mesh sieve	22½ per cent.	18 per cent.	18 per cent.	14 per cent.	14 per cent.	10 per cent.
76 × 76 ,, ,,	3 ,,	3 ,,	3 ,,	1 ,,	1 ,,	1 ,,
Specific Gravity :— (At Works)	3·15	3·15	3·15	3·10	Abandoned	Abandoned
Chemical Composition :—						
Proportion of lime to silica and alumina .	2·75 max.	2·85 max.	2·85 max. 2·00 min.	2·85 max. 2·00 min.	2·85 max. 2·00 min.	2·90 max. 2·00 min.
Insoluble residue—not to exceed	1·5 per cent.	1·5 per cent.	1·5 per cent.	1·5 per cent.	1·5 per cent.	1·5 per cent.
Magnesia—not to exceed	3·0 ,,	3·0 ,,	3·0 ,,	3·0 ,,	3·0 ,,	4·0 ,,
Sulphuric anhydride—not to exceed . .	2·5 ,,	2·75 ,,	2·75 ,,	2·75 ,,	2·75 ,,	2·75 ,,
Loss on ignition—not to exceed	—	—	2·0 ,,	3·0 ,,	3·0 ,,	3·0 ,,
Tensile Strength :—						
Neat—per sq. in. at 7 days min.	400 lbs.	400 lbs.	400 lbs.	450 lbs.	450 lbs.	600 lbs.
Neat—per sq. in. at 28 days min.	500 lbs.	500 lbs.	500 lbs.	$7\text{ days} + \frac{40{,}000\text{ lbs.}}{7\text{ days strength}}$	$7\text{ days} + \frac{40{,}000\text{ lbs.}}{7\text{ days strength}}$	Abandoned
Sand—per sq. in. at 7 days min.. . . .	120 lbs.	150 lbs.	150 lbs.	200 lbs.	200 lbs.	325 lbs.
Sand—per sq. in. at 28 days min. . . .	225 lbs.	250 lbs.	250 lbs.	$7\text{ days} + \frac{10{,}000\text{ lbs.}}{7\text{ days strength}}$	$7\text{ days} + \frac{10{,}000\text{ lbs.}}{7\text{ days strength}}$	$7\text{ days} + \frac{10{,}000\text{ lbs.}}{7\text{ days strength}}$
Setting Time :—	*Quick* : 10 mins. min. 30 ,, max. *Medium* : 30 mins. min. 120 ,, max. *Slow* : 120 mins. min. 300 ,, max.	*Quick* : Final 10 mins. min. 30 ,, max. *Medium* : Final 30 mins. min. 120 ,, max. *Slow* : Final 120 mins. min. 420 ,, max.	*Quick* : Init. 2 mins. min. Final 10 ,, min. 30 ,, max. *Medium* : Init. 10 mins. min. Final 30 ,, min. 120 ,, max. *Slow* : Init. 20 mins. min. Final 120 ,, min. 420 ,, max.	*Quick* : Init. 2 mins. min. Final 10 ,, min. 30 ,, max. *Medium* : Init. 10 mins. min. Final 30 ,, min. 180 ,, max. *Slow* : Init. 30 mins. min. Final 180 ,, min. 420 ,, max.	*Initial* : 20 mins. min. *Final* : 600 mins. max.	***Initial*** : 30 mins. min. ***Final*** : 600 mins. max.
Soundness :— Le Chatelier test—						
24 hours' aeration max.	12 mm.	10 mm.	10 mm.	10 mm.	10 mm.	10 mm.
7 days' aeration max.	6 mm.	5 mm.	5 mm.	5 mm.	5 mm.	5 mm.



Modern Cement-Storage Silos.

cement in 3 months. At the same time it has the same slow-setting properties of Portland cement and generally has not less than 1 hour initial set, thus giving plenty of time for mixing and placing. Another characteristic of aluminous cement is its resistance to the action of sea water and waters containing sulphates.

The following comparative table gives the results obtained on aluminous, rapid-hardening, and Portland cement :—

TENSILE STRENGTH

	Aluminous.		Rapid-hardening Portland.		Ordinary Portland.	
	24 hrs.	7 days.	24 hrs.	7 days.	24 hrs.	7 days.
3 sand, 1 cement	525	637	320	650	100	400

CRUSHING STRENGTH

	Aluminous.		Rapid-hardening Portland.		Ordinary Portland.	
	24 hrs.	7 days.	24 hrs.	7 days.	24 hrs.	7 days.
3 sand, 1 cement	6500	10000	3500	9000	800	5000
4 ballast, 2 sand, 1 cement . .	7810	8100	1750	5200	—	3000

The durability of aluminous cement concrete is shown by the following figures of tests put in hand in 1916, which show a steady increase in strength over a period of five years :—

4 parts aluminous cement, 9 parts gravel, 3 parts sand.

7 days	6080 lbs. per sq. in.
28 ,, ...	7695 ,, ,, ,,
90 ,, ...	8350 ,, ,, ,,
6 months . . .	8900 ,, ,, ,,
1 year	9360 ,, ,, ,,
3 years	9490 ,, ,, ,,
5 ,, ...	9700 ,, ,, ,,

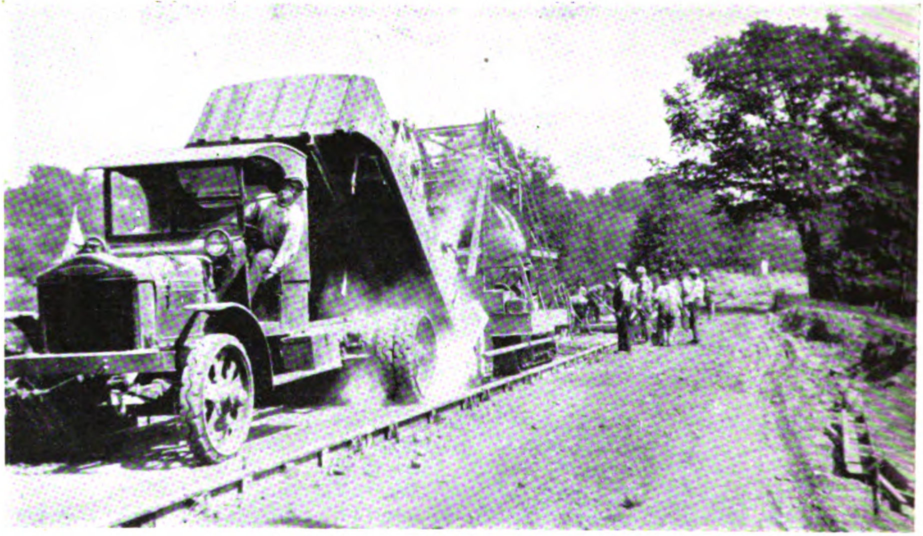
Tests show that aluminous cement does not exhibit the same rate of growth of strength as Portland cement. At 24 hours it had acquired most of its ultimate strength and is much stronger than Portland cement, but the latter gradually overtakes it, and in two or three months there is little to choose between them.

Where extreme rapid-hardening cement is required aluminous cement has been found to meet the case and is used for work where speed is essential, such as for the completion of concrete roads which are needed for traffic in 24 hours or less, tidal work, tramway track repairs, railway tunnel repairs, underpinning and foundations and concrete piles where time is short.

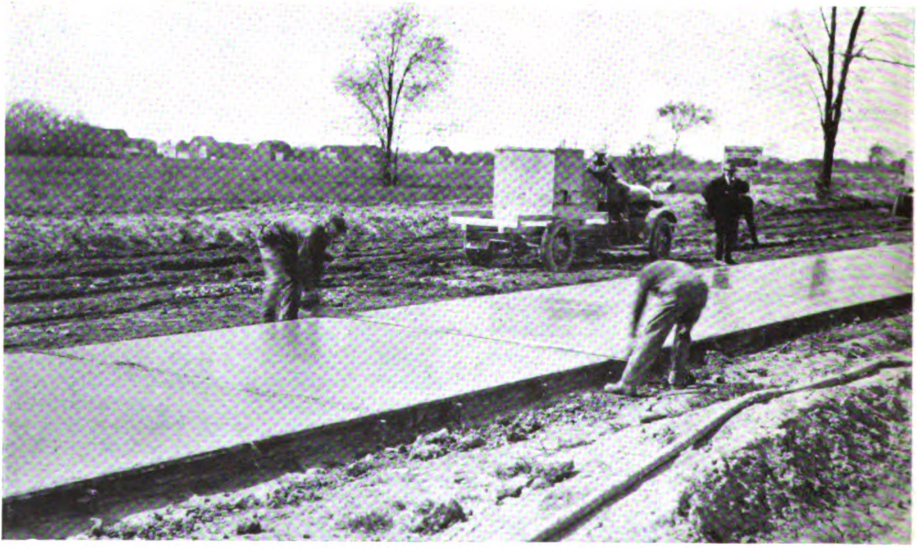
Pending Developments.

Investigations are now also taking place in the manufacture of a British aluminous cement which possesses even greater rapid-hardening qualities than those possessed by ordinary aluminous cement. Such cement has at 4 *hours* a tensile strength, when mixed with 3 parts of sand, of nearly 300 lbs. per sq. inch and a corresponding compressive strength of 2,750 lbs. per sq. inch.

There is thus no finality in the production of rapid-hardening cements, and it is impossible to predict what may be the constructional organisation of the future when these cements are in general use.



A Concrete Road in Virginia.
(*Lorry delivering batches straight into the mixer hopper.*)



A new Main Boulevard at Buffalo, N.Y.
(*Careful finishing is an essential feature of modern construction.*)

Concrete Roads in the United States. (*See p.* 79.)

Concrete Roads in America.

By R. A. B. SMITH, A.C.G.I., A.M.Inst.C.E.

In the course of a visit to the U.S.A. last summer the writer was impressed by the enthusiasm displayed by casual members of the community on the subject of their roads, and there is no doubt that whereas the propaganda of the Portland Cement Association undoubtedly turned the minds of highways engineers to concrete yet it is these roads themselves which have convinced the public that they are a good investment for their money.

The Prevention of Cracks.

In Great Britain the extremes of temperature which obtain are by no means comparable with those experienced in the United States, and it may be safely concluded that if concrete roads succeed in America then they should be as successful here, at any rate from the point of view of weather changes. So great are the frosts in that country that there is considerable movement in a vertical direction during a thaw, with the result that in the earlier roads there is a long zig-zag crack along the centre. This crack is filled each autumn with bitumen, and though of no disadvantage to drivers of vehicles, nevertheless is not attractive in appearance.

A solution to this trouble was soon found, and in practically all present-day designs the road is laid with one or more longitudinal joints. In Great Britain a similar design might be advantageous, though the movement of the ground is very much less over here; in fact, the longitudinal crack is almost unknown to the author in roads 20 ft. wide or less. In Ireland there are even wider roads with no longitudinal cracks, but there, as also in the Liverpool district, the range of temperature seems to be very small. These longitudinal joints are either similar to expansion joints or else dowelled, whilst in some cases they are plain butt joints.

There are cases where the engineer has kept the two concrete faces separate by oiling that first constructed and connecting the two parallel slabs with reinforcement, the idea being to prevent one slab rising more than another. The steel in the joint does not appear to rust, as the joint is kept sealed with a preparation largely composed of bitumen. There is a certain amount of variation in the actual application of the principle, and it is not possible yet to say which is the most effective method; it is however safe to say that the tendency of designers is to lay concrete roads in longitudinal strips about 10 ft. wide with transverse expansion joints at intervals of about 50 ft. where reinforcement is used, and 20 to 30 ft. where no reinforcement is used.

Construction of Joints.

It may be asked how these joints, both transverse and longitudinal, stand up to traffic conditions. In all recent construction (that is, on roads constructed during the last four years) the importance of a properly-constructed joint has been recognised. Previous to that all the joints were plain edges not bevelled or turned in any way.

It was found in practice that these edges tended to splinter and become ragged after a few years, and the bitumen filler took a rather more frayed appearance each time it was applied. To prevent this, great care is now being taken to round the arrises of the joints to ⅜-in. radius and the level of the surface on either side of the transverse joint is very carefully checked with a 6-ft. straight-edge.

The use of a tool shaped to the correct radius along one edge, and having the width of the flat face about 3 to 4 ins., is of great service when constructing a road of two or more longitudinal strips. The tamping of the second strip is off a form on one side and the existing concrete on the other. If the tool is not used the edge of the existing concrete is slightly uneven, and this unevenness is accentuated in the second strip, which is also slightly raised above the level of the first. The 3 to 4 ins. of smooth surface present as good a seat for the tamper as the timber or iron form on the other side, with the result that a much more satisfactory job is obtained.

I have mentioned at some length the care taken about the joints, as it is obviously a matter of extreme importance. The extra cost of doing the work correctly is very small, being the equivalent of, say, one man-day; at 1*s.* 4*d.* an hour and a day of 10 hours this is 13*s.* 4*d.*; and, spread over an average day's work of 320 sq. yds. (less than one-third of the American output), the extra cost is only ½*d*. per sq. yd. In England, actually the man is also available for other purposes, as it is impossible for him to be completely occupied.

Use of Skilled Labour.

It is of the utmost importance that contractors and engineers should realise the importance of efficiency. The labour-saving devices employed on concrete road construction lead to the employment actually of more skilled men at higher pay and less unskilled labour ; this is of the highest benefit to the country, and the increased output allows of more work being carried out annually for the same amount of money, as the overhead charges of the contractors are so much reduced.

In England the local councillor is apt to think he ought to see all the town employed on the road, whether skilled or unskilled, whilst in the U.S.A. a broader view is taken and it is realised that the use of efficient machinery means the employment of men to make machinery, to drive machinery, and to feed machinery.

If a contractor has plant he wants to find a job for it ; otherwise it is capital lying idle. If he only has men they go off his pay-roll as soon as the job is finished.

Handling Materials.

The whole subject of the handling of materials has been carefully studied in the U.S.A. The fine and coarse aggregates are not touched with a shovel or barrow from the time when they are disturbed from mother earth by a mechanical grab to the time they are deposited on the road-bed as fresh concrete. If the aggregate is delivered by rail it is raised into its proper hopper at the railway station by a grab, and when the hoppers do not require replenishing the grab empties the trucks on to the ground. At the bottom of each hopper is a measuring-box set by the inspector to deliver exactly the right amount of aggregate required for one batch. A lorry runs underneath the box and receives into each of its 5 or 6 compartments the correct amount of aggregate, and also a sack of cement for each batch ; very often the cement is not added till the batch is shot into the mixer, as weather conditions make it advisable to keep it under shelter on the job.

The lorry partitions are easily controlled by the driver, and on arrival at the mixer he backs the lorry up to the mixer hopper, tips it up, and releases each batch as fast as the mixer will take it. Just so many lorries are required as will make the supply of fresh concrete continuous. Usually buckets run the mix from the drum as far along the boom as is necessary, and four men spread it whilst two men follow closely up with the tamper. In England, with smaller mixers, only three men are necessary for spreading, but the mixers generally used in the U.S.A. deposit 18 to 21 cu. ft. of wet concrete per batch.

Surfaces.

Two more finishers work the belt and also check the work with a straight-edge as the tamper proceeds, and fill in depressions with fresh concrete, thus helping materially to obtain a road with no waves —in fact obtaining the good riding qualities considered so essential to-day. It has to be carefully drilled into these finishers that concrete will remain waveless if constructed waveless, and if constructed with waves these waves cannot afterwards be rolled out. As in addition the contractor is penalised if depressions are excessive, these finishers are kept up to the scratch by both the inspector and the contractor.

It must not be thought that traffic in the U.S.A. consists solely of light motor-cars, although there is no doubt that the highway engineers of ten years ago did not anticipate the great increase in lorry traffic which has taken place during the past three or four years. Many of the older roads were built too thin for present-day requirements, with the result that they have cracked considerably ; nevertheless many of these roads still present a very good riding surface, and the cracks on the old roads do not offend the eye to the same extent as they would do on a new road by reason of the fact that most of the surface, except at the edges, has been toned down to a dark colour by the oil-drippings over such an extended period.

The cracks are filled with a bituminous preparation once a year, and the annual cost of maintenance varies from 50 to 200 dollars a mile under these circumstances.

Another very interesting point is that the surface seems to retain its non-slip properties in spite of the gradual saturation with oil.

A typical State Concrete Highway, 40 feet wide.

(*Showing how the longitudinal strips act as efficient traffic guides.*)

Looking Ahead.

The modern main road design allows of an average depth of from 8 to 9 ins. where the traffic is very heavy, with a reduced design according to the probable future traffic requirements. In the offices of the State of Pennsylvania is a large map on which the various areas are coloured according to their probable development during the next twenty years. From this map the State Engineer calculates the probable volume of traffic on his various roads at that period ahead, and when designing allowance is made for these future requirements. There are, I believe, few if any counties in England where an effort is made to calculate future requirements even when new roads are constructed, and it is symbolical of the value of concrete that it has made it possible for highway engineers to take useful advantage of these estimates. Of course, not only the thickness of the concrete is based on these calculations but also the necessary final width of the road. When driving through villages it is very noticeable that sometimes the sides of the main streets are paved in concrete; sometimes the 20-ft. strip is in the centre and not the sides, and again in other cases the whole width is concreted. At first it appeared to be the whim of the local engineer, but on inquiry it was found that the State owns the centre strip and the village the side strips. In consequence, when the State had formulated an advanced programme and laid its concrete early, the village often waited till the traffic warranted the remainder being permanently paved; and *vice versa*, when the State programme was delayed, the village concreted the side strips in order to have at any rate a portion of the road in first-rate condition. However, the full width is rapidly becoming the most popular owing to its cleanliness.

Research.

There is one very important side of highway engineering in the United States which has little or no counterpart in this country, and very regrettable it is that we are so far behind them in this respect. I refer to their research works. That carried on at the expense of the Federal

[*Messrs. Tawse & Allan, Engineers.*

Bridge over the River Don, Inverurie.

Government is done under the auspices of the Bureau of Public Roads at Washington, under the very able control of Mr. Goldberg. I heard that this officer is unfortunately to be lost to the Government, as a commercial firm has realised his value and has succeeded in capturing him. Nevertheless, the good work he has initiated must go on, even though there be some difficulty in choosing a successor. The whole system of research is elaborate and complete ; every possible phase is examined that may lead to further knowledge of road engineering ; and it is safe to say that the thousands of dollars spent at Washington have saved the public millions.

It was, of course, as a result of this research work that the value of concrete was not only recognised but considerably enhanced. I am not sure that I am right in saying all the States in the U.S.A., but at any rate all those States which I visited, also had well-equipped laboratories and are now working in conjunction with the Bureau of Public Roads in order to advance further their knowledge of the important subjects they have in hand. In addition, there is an independent laboratory devoted to research work at Chicago, namely the Lewis Institute, where Professor Abrams, with the assistance of Mr. Gonnerman, has studied the question of aggregates to the benefit not only of road authorities but designers in concrete generally.

At Washington is a large circular track on which are tested all conceivable surfacing materials. At the time of my visit bitumen carpeting was being tested for " creep," and a test on concrete surfaces had just been completed. It is by no means an exaggeration to say that so great is the belief of engineers in concrete surfaces throughout the country that something like 75 per cent. of the money devoted to research is spent in investigating the possibilities of concrete.

In closing I must refer to a stretch of concrete on Sheridan Boulevard, Chicago. This is the main boulevard and carries several omnibus services in addition to hundreds of motor-cars ; nevertheless the concrete is a huge success and is demonstrating here that it is as valuable in the heart of a city as it is on the country roads. It was believed at one time that difficulty of repairing made the use of the material impossible in places where the traffic was dense, but with the arrival of rapid-hardening Portland cement that difficulty no longer exists, and repairs can be carried out at a speed hitherto unknown.

Concrete roads have come, and come to stay and multiply. No amount of conservatism can stop them, and many a man who has constructed a concrete road almost unwillingly, and merely so as to be able to say that he had constructed one, is now numbered amongst its staunchest advocates.

Progress in Concrete Products.

By T. J. CLARK.

In the history of a nation a period of twenty-one years is so short that very little development in the national life usually takes place. In the history of an industry, on the other hand, twenty-one years may be a comparatively long period if we have regard to the developments which take place within it. Such a period is the last twenty-one years in the manufacture of concrete products in this country.

Previous to that time the use of concrete was confined mainly to mass work, but even then a few far-sighted individuals had realised the vast possibilities of concrete, both plain and reinforced, for every-day uses, and a few—a very few—firms had already been formed for the manufacture of products of this nature. The number of such firms was so small that they could be counted on the fingers of one's two hands; to-day there are over four hundred.

It is interesting to glance through the first issue of *Concrete and Constructional Engineering*, to note the character of the subjects therein dealt with, and to compare them with those of more recent issues. In the first number there was only one reference to concrete products of the character we are considering, and that was a description of certain types of concrete railway sleepers being tried in America.

Pioneer Work of the Railway Companies.

Among the first to take up the manufacture of concrete products on a large scale in this country were the great railway companies, the pioneers being the Great Western Railway. The growing shortage of the world's timber supply led this company to look round for a substitute. This they found in concrete. Early in the period under review, the Company began making concrete platform slabs and copings in a yard about a quarter of an acre in extent at Taunton. These were followed by fence-posts in 1910, during which year enough posts were made to fence in a length of about two-thirds of a mile. To-day the annual output of fence-posts alone is sufficient to cover a distance of something like 45 miles.

From the little ¼-acre yard, this depot has developed to such an extent that it now covers nearly six acres of ground, and the list of the articles produced is long and varied—too long for them even to be enumerated here.

In 1913 the then London and South Western Railway followed the example of the Great Western, and equipped a concrete depot at Exeter, and here again the same expansion and development proceeded. At intervals other companies fell into line, until now all the great railways have their own concrete yards for the production of articles and structures for their own use.

At first concrete was only employed on the railway as a substitute for other material, but so successfully has it been used, and so efficient and so economical has it proved, that it is no longer regarded as a substitute, but as a sound con-

[*Mrs. Phœbe Stabler, A.R.B.S., Sculptor.*

Head carved in Concrete.

structional material in itself, which for many purposes is rapidly superseding not only wood, but iron, steel, brick, and even stone.

The development of the use of concrete on the railways is only typical of its development in every direction—in industrial works, on estates and farms, by municipal and county authorities, in the building trade, and in the home.

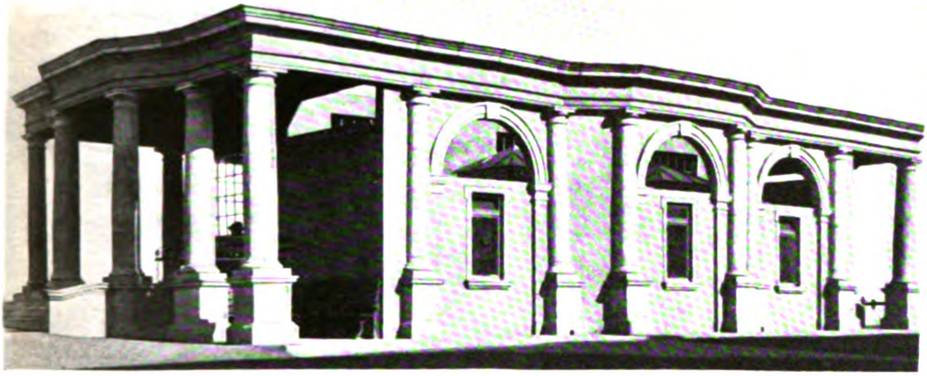
Industrial Works.

Concrete buildings for industrial purposes have been erected for many years, but during the last twenty-one years new uses for concrete in connection with various industries have been discovered. In many industries, for example, it has been found that concrete, besides being damp-proof, will resist the action of oils, acids, and chemicals more completely than any other material. Many concrete floors have therefore been laid down in industrial works during recent years. Concrete tanks, too, are now coming into common use for industrial purposes, not only for water, but for holding various chemical solutions. Breweries, for example, have found that concrete is suitable for fermenting vats, and the latest reports show that those that have been constructed have proved satisfactory in every way. Collieries are using concrete to an increasing degree for the construction of pit-head gear, for pit-props, the lining of shafts and galleries, and many other purposes. Concrete chimney stacks are now being largely adopted, and gas companies have found that the most efficient and the most economical form or gasholder tank is that of concrete. These are only a few typical examples of the advance made in the use of concrete for industrial purposes during recent times.

Estates and Farms.

Coming now to the use of concrete on estates and farms, the development here has been very great, as a glance through the pages of this journal will amply demonstrate. There are many purposes to which concrete is now being applied that would never have been dreamt of a generation ago. How many, for example, at that time would have dreamt of housing their pigs in concrete styes? And yet to-day there are hundreds of these structures in use. The practice of ensilage, too, has been steadily on the increase in Great Britain during this period. Early in the century the only concrete silos in use were square pit silos, but these did not prove satisfactory owing to the disadvantage of their shape. Then came the circular tower concrete silo such as we know it to-day, the first of which was erected about 1908, and where adopted this type has proved

Porous Concrete Tennis Court at the Royal Botanic Gardens.



Reinforced Concrete Shelter at Herne Bay.

such an asset to the farmer that scores of them are now to be found throughout the country. In America they are almost universal. As in the case of the railway products, considerations of space forbid the enumeration of the multifarious ways in which concrete is employed on estates and farms.

Public Authorities.

In addition to roads there are many ways in which concrete has been steadily replacing other material on public works—concrete sewer-pipes and water-mains, for example—and although the former were made as far back as 1875 it is only in recent years that they have become almost universal. Other comparatively new applications in this connection are lamp-posts, telegraph posts, gullies, manholes, and catchpits, and perhaps the latest is the public telephone kiosk which is being adopted in several localities.

Tennis Courts.

Such is the popularity of the game of lawn tennis that a very natural desire to play at all seasons of the year has made itself felt. To meet this need various types of hard courts have been devised. Among these concrete courts, plain and coloured, have been tried with more or less success; these, however, were courts with a hard, impermeable surface. A tennis court, red in colour, has now been produced consisting of a concrete so porous that water poured on the surface from a bucket entirely disappears in from 15 to 30 seconds. The advantage of this after a shower of rain is so obvious that it need not be enlarged upon.

Dwelling Houses.

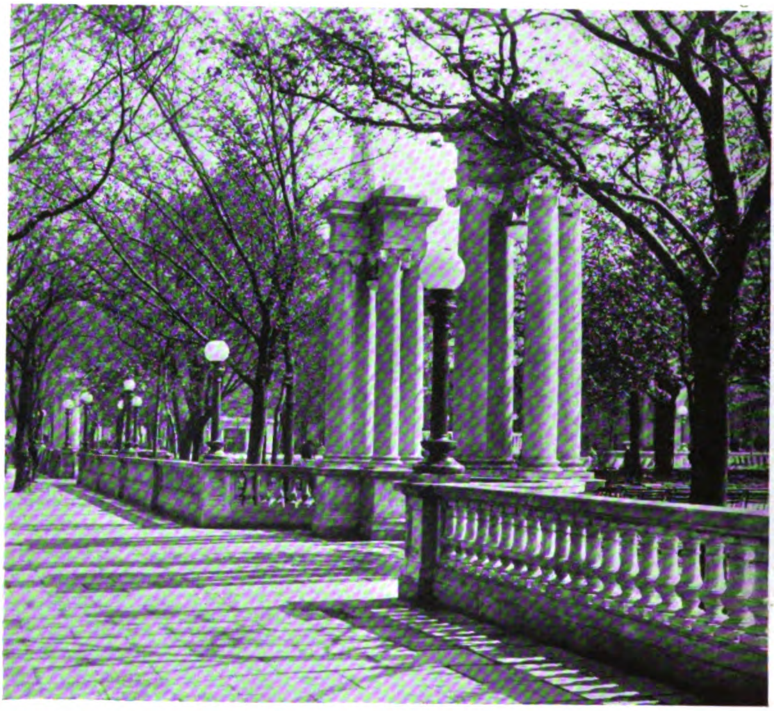
Another direction in which concrete has made rapid strides is in its use for the erection of dwelling-houses. Twenty-one years ago concrete dwelling-houses were comparatively few and far between—exactly what the number was it is impossible to say—but latterly the shortage of bricks and bricklayers has been so acute that concrete houses have become a necessity in order that the many housing schemes throughout the land may be carried out. So far as figures are available the number either erected or in course of construction to-day is between forty and fifty thousand, and possibly exceeds the latter figure.

Machinery.

The great increase in the use of concrete has naturally created a greatly increased demand for machinery for making concrete products. At the end of 1905 the number of makers of machinery for this purpose was five; to-day the number is over sixty, while if makers of mixers and other machinery for large works are included the number is 120.

The Artistic Side.

So far we have dealt mainly with numbers as indicating the advance of the industry, but there is another develop-



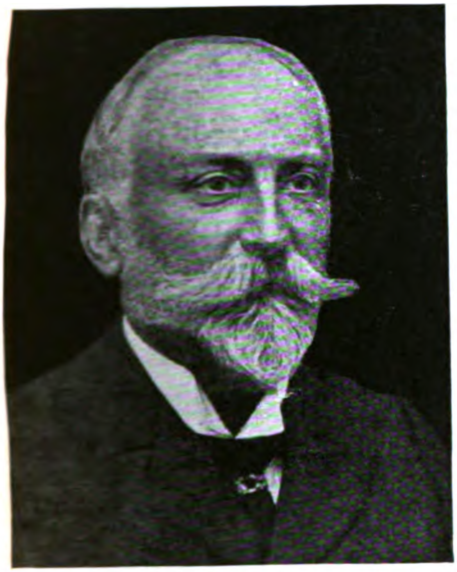
Band Enclosure, Lord Street, Southport.

ment which has been quietly taking place, and that is the development of the artistic side of concrete. There is no doubt that in the early days much of the work done was crude and uninteresting in appearance. In their enthusiasm for concrete the strong, the durable, the hygienic, the workers of that time had no vision of the possibility of concrete the expressive, the satisfying, the beautiful. All that has now changed. Concrete work is being produced to-day which, as regards design, colour, and texture, shows that in concrete we have a medium by which great beauty may be expressed and which is capable of rising to the highest artistic level.

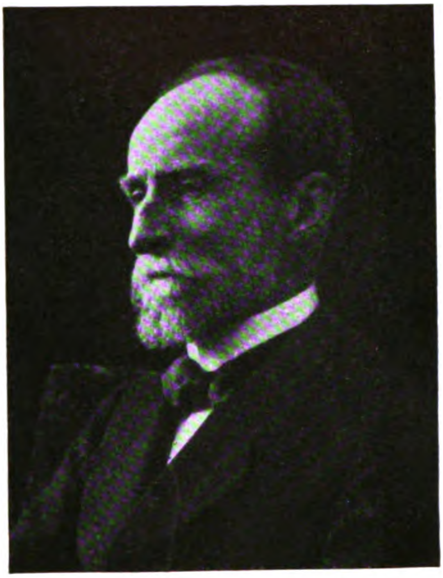
A form of concrete that is now achieving great popularity is that which is variously known as "cast," "synthetic," or "reconstructed" stone. In this form concrete may be made to represent any natural stone at about half the cost. The value of this for architectural purposes is obvious, and it is now being used to an increasing degree not only to take the place of natural stone for dressings, but also to form the entire external face of buildings such as churches, theatres, commercial buildings, and pavilions, and for ornamental structures such as pergolas, arcading, balustrading and panelling.

Cast stone has recently been successfully used for statuary, by some of our leading sculptors. The figure by Mr. Doyle-Jones (*see p.* 6) was first cast in a special mould, and, when the concrete had set, the surface was lightly tooled. Several firms are now turning out garden ornaments in cast stone; among these are such products as sundials, bird-baths, fountains, garden seats and figures of various kinds.

Some Pioneers in Reinforced Concrete.



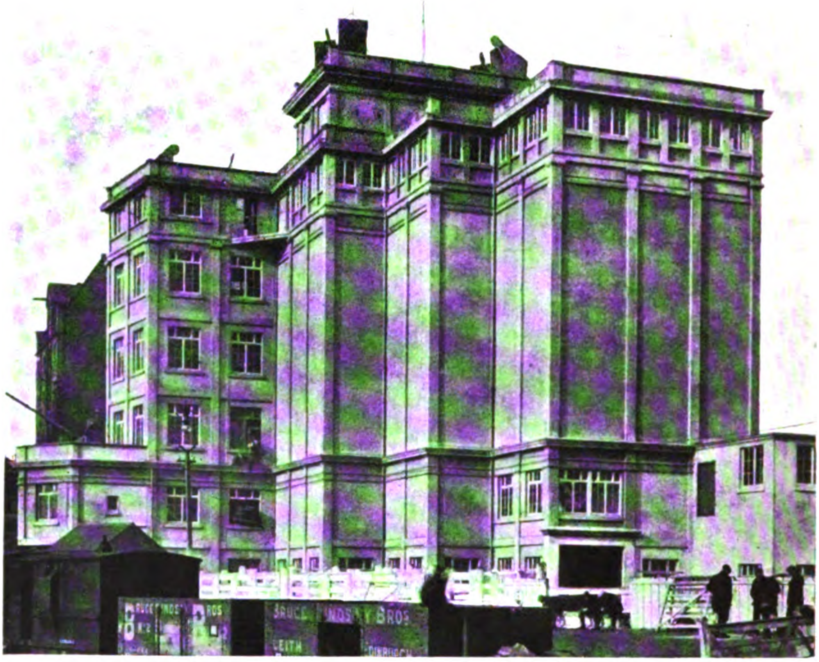
Edmond Coignet.
(1853–1915.)



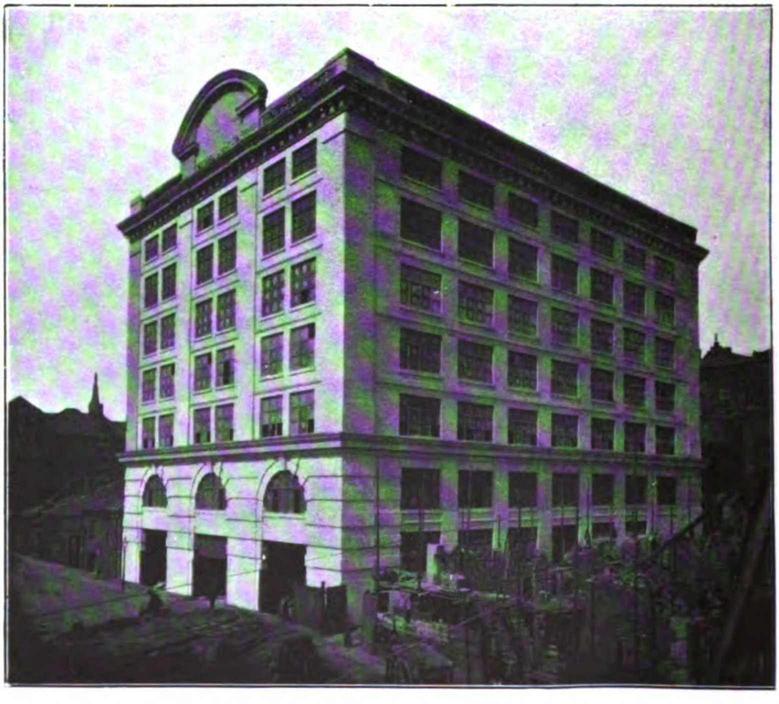
Armand Gabriel Considère.
(1841–1916.)

François Hennebique.
(1842–1921.)

L. G. Mouchel.
(1852–1908.)



Grain Silos at Dunston-on-Tyne (built 1901).



Warehouse at Newcastle-on-Tyne (built 1900). (*See p.* 89.)

The First Decade of Reinforced Concrete in the United Kingdom (1897-1906).

By T. J. GUERITTE, B.Sc. (Paris), M.Soc.C.E. (France), M.I.Struct.E.

(*Managing Director, L. G. Mouchel & Partners, Limited.*)

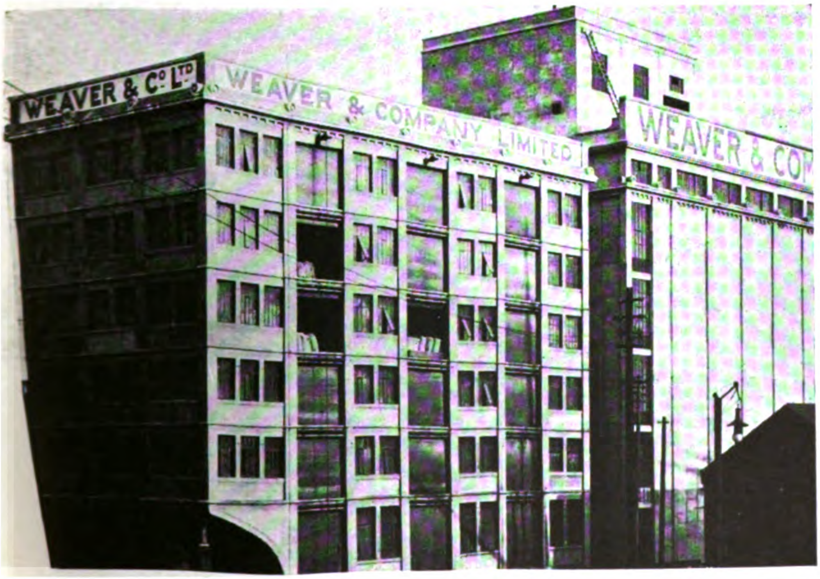
LEAVING aside a few examples of concrete structures in which a few iron rods were embedded haphazard, it was in 1892 that the late François Hennebique gave the first impetus to the scientific combination of the two materials known as reinforced concrete. His extraordinary intuition of the possibilities and intrinsic properties of the new material rendered his first applications, in Belgium and in France, so bold and startling that some of them have hardly been exceeded in daring to this day.

Introduction of the Hennebique System.

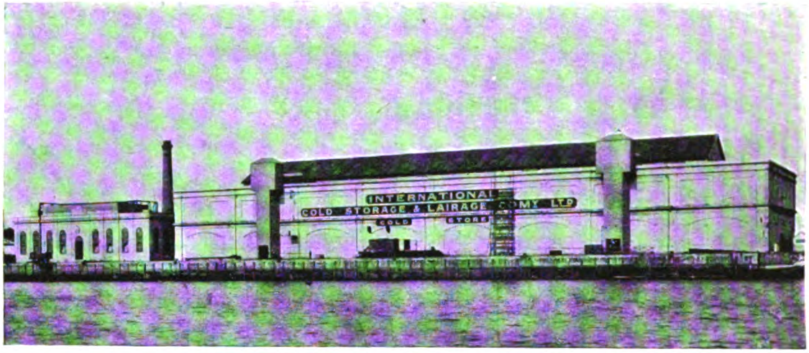
The introduction of the process in this country was due to the enthusiasm of my late senior partner, L. G. Mouchel, who in 1897 saw carried out his first designs at Southampton (a river wall founded on ferro-concrete piles) and at Swansea. It is worthy of notice that from the very first L. G. Mouchel had introduced in this country the latest development in reinforced concrete, viz. piles, which were to become so widely used in this country, but which at that time had never yet been used on a big scale even in France; and in 1897 embodied in the design of Weaver's Flour Mills at Swansea one of the most striking features of reinforced concrete, viz. its adaptability to heavily loaded cantilever constructions. We have by now grown accustomed to such features, but engineers of my own generation will remember how startled were British engineering circles in those days by the unaccustomed boldness of those early works.

Early Reinforced Concrete Structures.

The first reinforced concrete jetty of some magnitude ever built was that at Woolston on piles 10 in. by 10 in. The work was carried out (in 1899) with care and with good materials, and a recent inspection showed it to be in a perfect

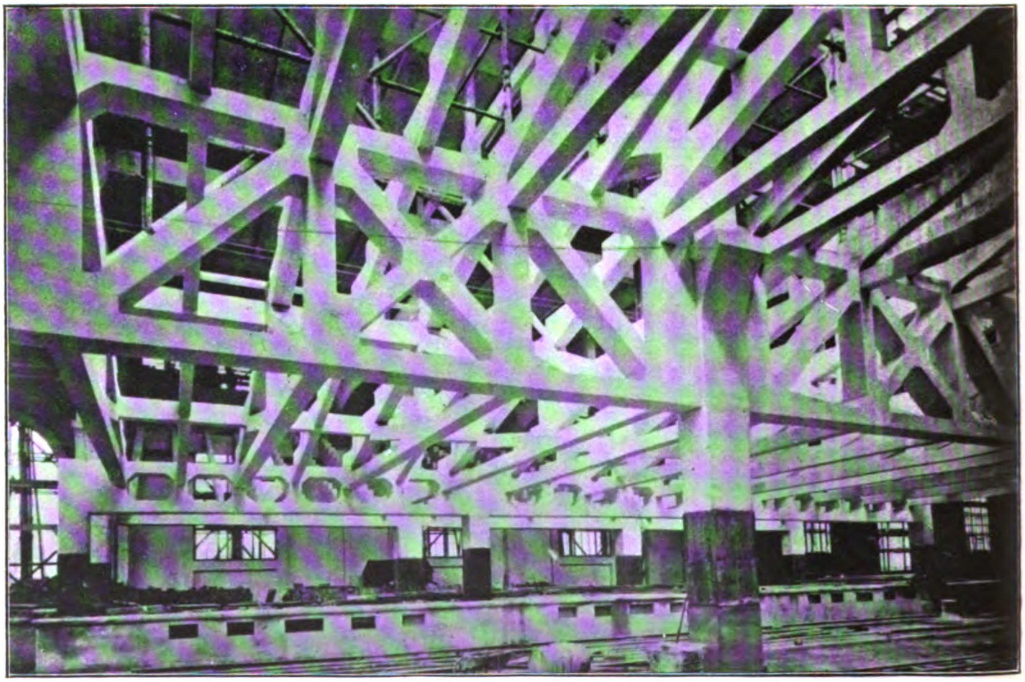


Flour Mills at Swansea (built 1897).



Cold-Storage Buildings at Southampton (built 1900-1904).

state of preservation after twenty-five years, and this notwithstanding the fact that the scantlings were so small as to allow of only ¾-in. cover to the main bars. A comparatively thin layer of really good concrete affords, in fact, far better protection to the steel than a thick layer of more indifferent material. In 1900 the C.W.S. Warehouse at Newcastle-on-Tyne was another eye-opener to many architects and engineers. Each of its seven floors had to carry 6 cwts. per sq. ft.; the ground was very soft, the adjoining building being founded on piles 40 to 50 ft. long. To avoid expenditure in that direction the building was designed as a monolithic box, the basement floor acting as a raft with a



Goods Station at Newcastle-on-Tyne (built 1903-5).

maximum thickness of 2 ft. 6 in. Allowance was made for the building sinking 6 in., which it practically did.

As an example of the increase of strength of reinforced concrete structures with age, it is interesting to note that the flat roof of the warehouse, designed for a superload of 56 lbs. per sq. ft., has been used since 1911 as a floor loaded normally at 1½ cwt. per sq. ft., a further story having been added. Tests carried out in 1910 show this floor to be stronger under that load than it was under 56 lbs. when tested a few weeks after completion.

The range of application grew rapidly. The huge cold storage built at Southampton between 1900 and 1904, founded on over 1,000 piles, remained for a long time the biggest in the world, and may still be so. It may not be out of place to recall that in those early days of ferro-concrete piling it was thought necessary to cast the piles vertically. It was in Southampton that, shortly after, 1,900 piles were for the first time moulded flat.

It was also in these days of active research and experiment that the first hollow piles were made in accordance with the Mouchel patent for use in very soft ground on the Tyne. Piles of that type were built up to 20 in. by 20 in., the piles of the Tyne Dock Crane Jetty having a length of 90 ft.

The first grain silo built in reinforced concrete in this country, with bins 14 ft. square and 45 ft. deep, was that built at Dunston-on-Tyne in 1901 for the C.W.S. The same owners instructed Mr. Mouchel in 1906 to design the first circular silos built in this country which

Cooling Towers at Liverpool.

remain to this day the biggest diameter silos (46 ft.; depth of grain 70 ft.).

As early as 1900 Mouchel had patented the grouping and protecting of piles by means of cylinders for heavy jetty work, a feature which is now universally used. The first application was at Dagenham, in 1900.

A structure which attracted considerable attention, being at that time (1903–5) the largest railway goods station in reinforced concrete, was that at New Bridge Street, Newcastle-on-Tyne. The main beams, 52 ft. span, 38 ft. apart, and carrying the three upper floors were at that time the record for such heavily-loaded floors. The building contained also an automatic storage for flour bags, which had necessitated the provision of lattice girders and trussed beams in reinforced concrete which constituted an *ensemble* never before met with, and of which the illustration, p. 90, gives a somewhat inadequate idea.

Examples of water tower construction in those early days are found at Bournemouth (1900), and Newton-le-Willows (1904; 300,000 gallons).

Big culverts such as at Ouseburn, Newcastle-on-Tyne, nearly half a mile long and buried later under 100 ft. of filling (width 33 ft.), were already in evidence in 1905; coal bunkers were built as early as 1904 at London, Leeds, etc.

Bridges.

It will be seen that in most spheres of application those works of the first decade have hardly been surpassed in daring or magnitude. It seems to be only in bridge construction that progress was slow, not as regards numbers, as even in those early days the number of bridges carried out was great, but as regards span. Burlington Street Bridge, Liverpool (1903), is interesting as an example of very small rise vault, span 50 ft.; and Waterford Viaduct (Ireland), 720 ft. long, founded on piles 62 ft. long was already a work of great magnitude. But it was only in 1907 that spans approached 100 ft., and no bridge of a span exceeding 150 ft. had been constructed in this country until 1922, when Reading offered us a bridge of 180 ft., a sudden jump being further recorded for the Berwick Bridge now in course of erection (span 361 ft.).

Water Tower at Bournemouth (built 1900).

Some Early Enthusiasts.

It may perhaps not be out of place, at the end of this short historical sketch, to mention the names of eminent British engineers or architects who by their open-mindedness contributed in helping the new industry during its first ten years. Among those—who alas! are now departed—were: William Bell, of the N.E. Railway; Jacomb Hood and W. R. Galbraith, of the L. & S.W. Railway; W. H. Hunter, of the Manchester Ship Canal Company; A. G. Lister, of the Mersey Dock and Harbour Board; W. W. Squire, of Bristol Docks; John Wilson, of the G.E. Railway; F. E. L. Harris, of the C.W.S.; and C. S. Meik. Happily there are still with us an increasing number of architects and engineers whose realisation of the possibilities of reinforced concrete will ensure that progress in the future will be even more rapid than the phenomenal progress during the past quarter of a century.

Twenty-One Years' Development in Reinforced Concrete Design.

By **H. E. STEINBERG, M.Inst.C.E.**

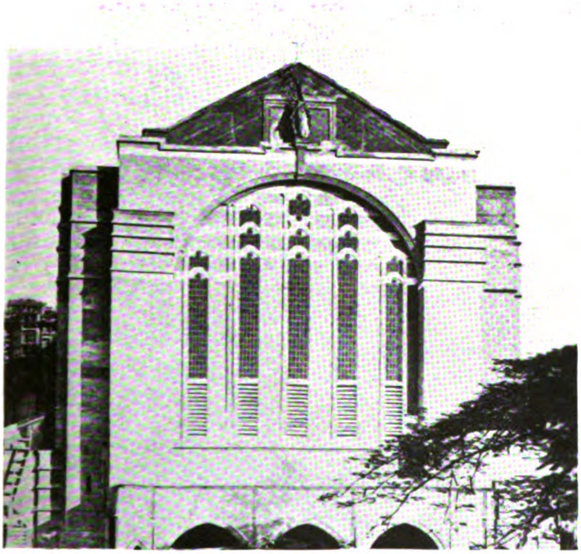
(*Manager, Considère Constructions, Limited.*)

No review of the development of reinforced concrete would be complete without reference to the pioneer work of Monsieur A. Considère. At a time when the majority of designers were content to employ empirical formulæ for the calculation of stresses, M. Considère, as a trained civil engineer of high mathematical ability, devoted his attention to devising formulæ for the determination of stresses in the concrete and steel based on logical reasoning. The present standard equations were the result.

Introduction of Spiral Reinforcement.

Considère's name is, however, most strongly associated with the original idea and the development of the use of spiral reinforcement with concrete in compression. He was apparently the first to realise that the strength of concrete can be enormously increased by the introduction of a steel spiral. Confirmatory experiments were subsequently made by the French Government, and others in Switzerland and Germany, with the result that the spiral type of reinforced column and reinforced concrete pile became accepted as the most efficient arrangement of reinforcement.

Somewhat unfortunately, experimenters in the United States attempted to improve on Considère's methods by departing from his recommendations as to the best relationship between the volume of concrete, the volume of spiralled reinforcement, and that of the longitudinal steel bars; consequently their results, although good, did not indicate the superiority of the method as clearly as they might have done.



[*The late Leonard Stokes, PP.R.I.B.A., Architect.*

Georgetown Cathedral, Demerara, during Construction.

Continuous Beams.

Considère was also one of the first engineers to recommend the full recognition of the theory of continuous beams in designing reinforced concrete structures, and he was a pioneer in the introduction of expansion joints in long bridges and wharves, as well as temporary articulations in arched bridges.

So long ago as 1908, Messrs. Considère Constructions, Ltd., who have developed the Considère system in this country, designed a multi-span bridge, about 750 ft. long, in North London, which was cut into sections by expansion joints every 200 ft., the main beams in each section being designed as continuous girders over a series of trestle supports. These refinements of design have now become almost universal, but the advantage, and in many cases the necessity, of introducing temporary hinges in arched bridges is not yet fully appreciated.

Considère also investigated the adhesion of concrete to reinforcement, and from his experiments evolved the well-known Considère hook, which is now universally adopted and has completely displaced the old fish-tail form of anchorage.

Piles.

One of the most useful applications of reinforced concrete is for pile foundations, and, when properly designed, pre-cast piles of the Considère type have been successfully made and driven for lengths up to 87 ft. Many thousands of Considère piles were used in connection with the Aberdeen Harbour Wharf Extensions, and others up to 75 ft. long were employed in the foundations of Dover Harbour Station building.

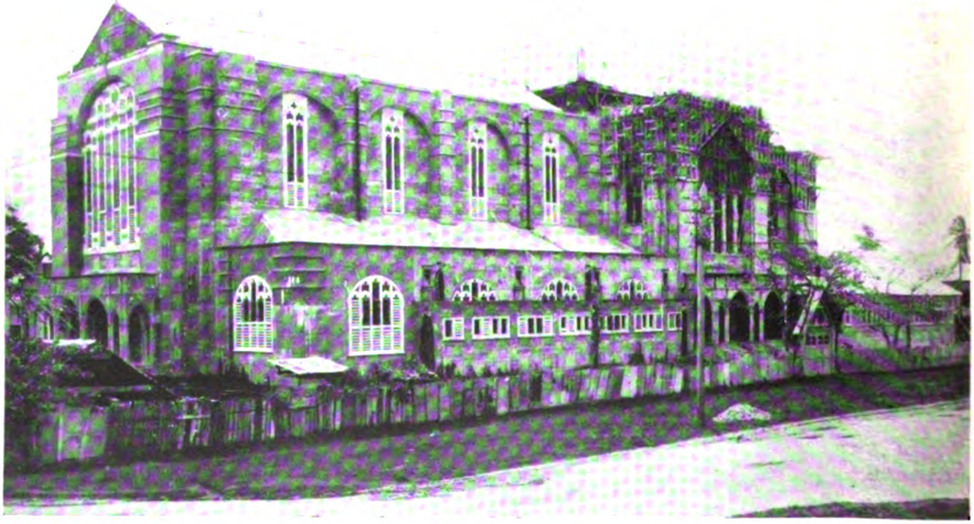
Early Considère Structures.

Some illustrations of early work done by the English company may be of interest, for comparison with modern work, thus showing the development in design during the past twenty years.

Angel Road Bridge over the (then) Great Eastern Railway was designed in 1908, and consists of seventeen spans of 42 ft. 9 in. each. This was one of the earliest bridges in this country in which expansion joints were used, and in which the beams were designed as continuous girders. In architectural appearance the bridge undoubtedly leaves much to be desired, but structurally, beyond a few rust marks in the thin parapet walls, due to lack of trained steel-fixers and benders, it is as sound as the day it was completed.

This bridge now forms part of the North Circular Road, and close to its western extremity Messrs. Considère Constructions have recently designed, for the Middlesex County Council, a bridge over the River Lea Navigation. This is now in course of construction, and forms the eastern terminal of the new Lea Valley Viaduct. When these works are completed it will be possible to compare one of the pioneer efforts in scientific design with modern developments.

The wharves at Aberdeen were constructed in 1910 by Mr. R. Gordon Nicol, Aberdeen Harbour Engineer. A recent inspection of these wharves shows that, provided proper precautions are taken in design, and in mixing and ramming the concrete, no danger need be feared from the corrosive effect of



[*The late Leonard Stokes, PP.R.I.B.A., Architect.*

Georgetown Cathedral, Demerara.

Wharves at Aberdeen (built 1910).

sea-water. The work was constructed as far as possible with precast units, and the illustration on this page shows one of the main counterforts ready to be lifted into position. The wharves are over 2,000 ft. long, and after fifteen years there are neither rust marks nor cracks to be observed. The arrises of the piles and walings are clean and sharp, and the surface of the concrete smooth and free from pinholes.

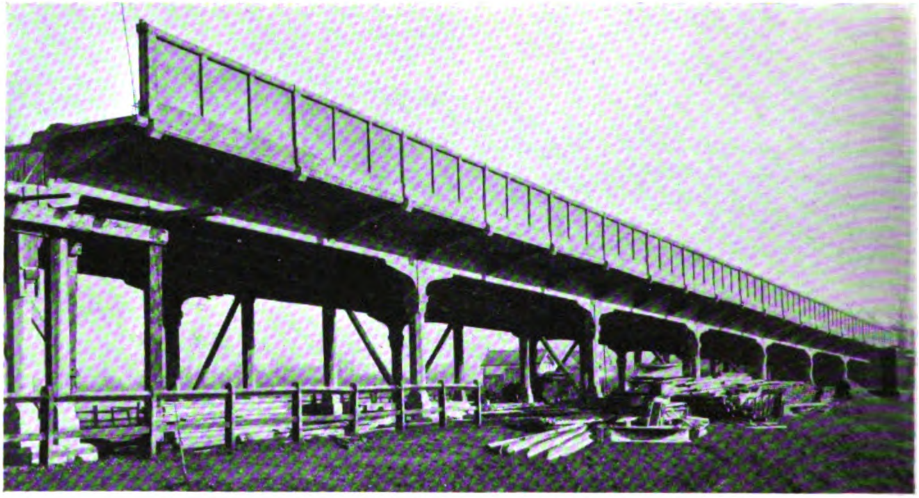
The reconstructed Continental Quay at Newhaven is over 1,600 ft. long, and was designed not only to give greater accommodation but also to act as a means of strengthening the mass concrete retaining wall which formed the original Quay. The whole length of this mass wall had been undermined by the influx of sea-water, and had to be underpinned below low-water level, the underpinning being supported on reinforced concrete piles which were carried up to form the face of the new Quay.

Wharves at Aberdeen: Counterfort Ready for Lifting into Position.

An example of a modern arched bridge, which has, however, been constructed long enough to show the permanence of reinforced concrete work if properly designed and carried out, is the bridge over the river Mersey at Warrington, which is 80 ft. wide by 134 ft. span. Temporary hinges of heavy spiralled concrete were introduced at the crown and springings, and the use of this device is undoubtedly responsible for the fact that no cracks are apparent anywhere in the bridge or in the parapets. The bridge was constructed in 1912.

A novel type of reinforced concrete bridge is that near Aberdeen (*see p.* 82). This bridge was designed to replace an old three-span stone arch, and as the abutments and the river piers of the arched bridge were in good condition it was decided to make use of them in designing the new structure. In order to eliminate, as far as possible, oblique thrusts, the new bridge was designed as a double cantilever, the extreme ends being provided with sliding plates so that movement due to variations of temperature can take place without introducing unknown stresses in the reinforced concrete superstructure.

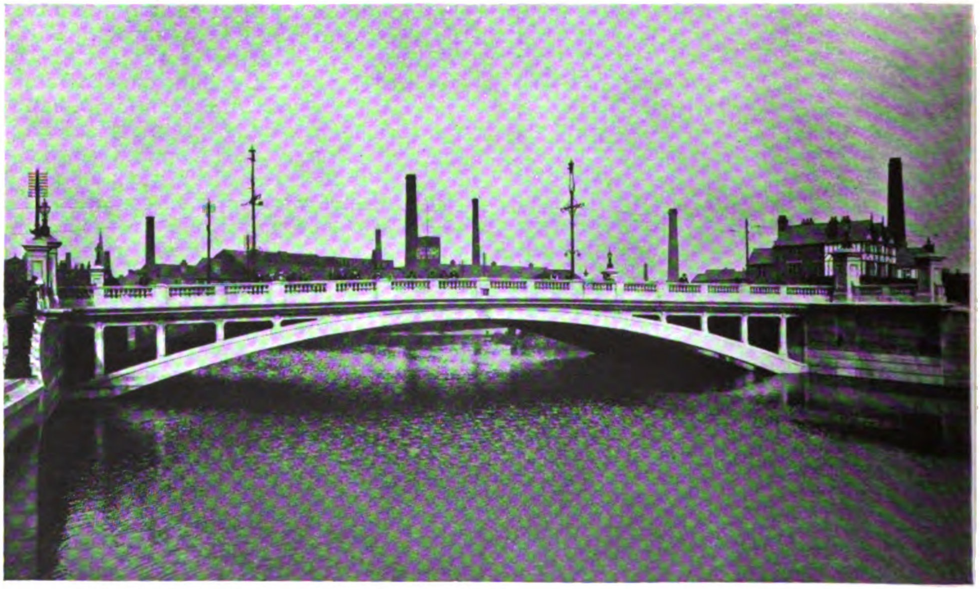
One of the most up-to-date examples of reinforced concrete design at present under construction in this country is undoubtedly the new bridge over the Clyde, in the heart of Glasgow. Parliamentary powers were obtained for the construction of a bridge of three spans,



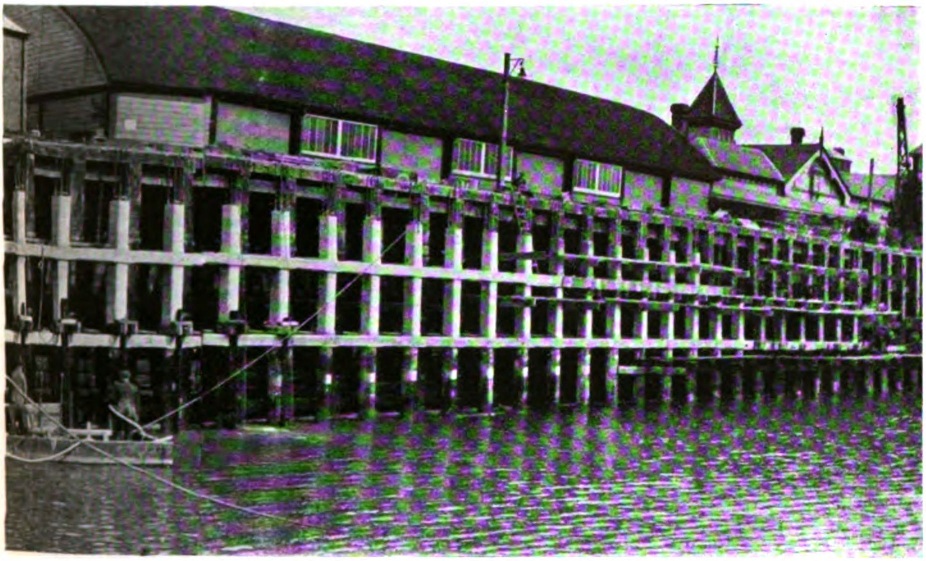
Angel Road Bridge (built 1908).

and the stipulations in regard to roadway levels and clearances above high-water made it impossible to design a series of arches. The structure was therefore treated as a double cantilever bridge, the connecting link in the middle being made integral with the cantilevers.

In order to allow free movement, due to variations of temperature, the whole superstructure will be carried on steel roller-bearings. The river piers and abutments are carried on reinforced concrete caissons, those over the river piers being provided with a false bottom floated into position. The photograph is from a model of the bridge.

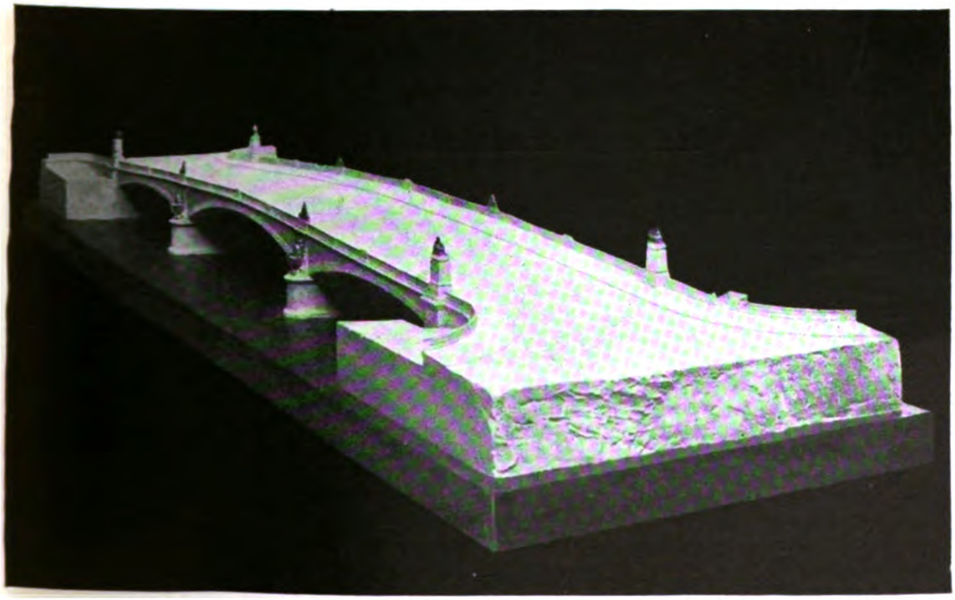


Warrington Bridge.

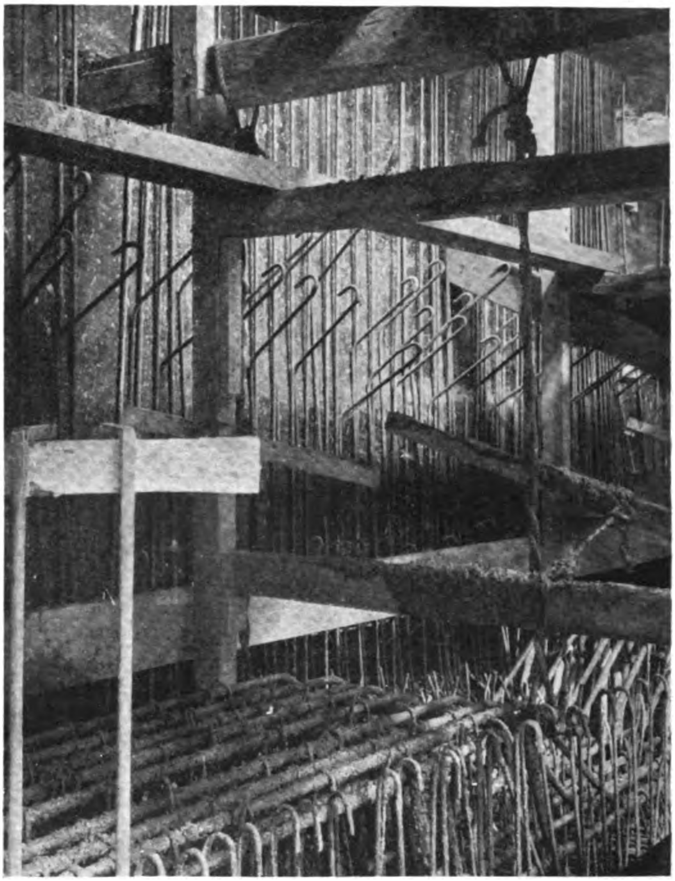


East Quay, Newhaven Harbour.

What was then a pioneer application of reinforced concrete was its use for the construction of the retaining wall for the Royal Insurance Building in Lombard Street, in 1910. The wall was designed as a self-supporting unit, and exerts no thrust on the building. It is 25 ft. high, and in order to avoid any possibility of subsidence in the roadway during the construction of the wall the contractors



Oswald Street Bridge, Glasgow.



Retaining Wall in Lombard Street (1910).

were advised to leave in place the poling boards and walings, and shutter the inside face of the wall only.

This method of construction possesses many advantages, both from the points of view of safety and economy, and has since been used for many other retaining walls designed by the firm, a recent example being for the new building under construction for Messrs. John Barker, Ltd., in Kensington.

The use of reinforced concrete for the construction of swimming baths was one of its earliest applications in this country, but some of the results were not entirely satisfactory. These difficulties have now been entirely surmounted, and reinforced concrete is now used for the majority of baths, not only for the swimming ponds themselves, but also for the roofs and balconies.

In a modern bath a roof has been specially designed to give freedom from condensation by introducing a cellular formation in reinforced concrete ; a number of baths have now been designed in which this feature is included.

The cathedral at Georgetown, Demerara, is being built to the reinforced concrete designs of Messrs. Considère Constructions, Ltd.

The Future of Reinforced Concrete.

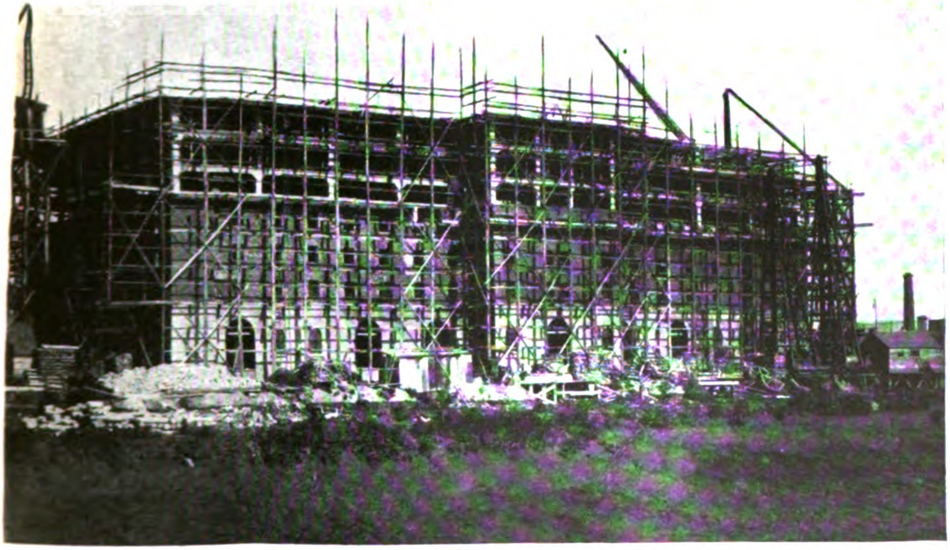
By G. C. WORKMAN, M.S.E., M.I.Struct.E., M.Soc.Eng.Civ.(France).
(*Managing Director, Edmond Coignet, Limited.*)

JUDGING by the enormous amount of reinforced concrete work which has been carried out in this country and abroad it can no longer be said that this is a new material which has not been sufficiently tried to warrant its being adopted with the utmost confidence. The number of failures which have occurred during the past ten years are comparatively few, and in almost every case these failures can be traced to the lack of experience of the contractors rather than to faulty design. It may be safely asserted that there have been no more failures of reinforced concrete structures than of steel or masonry works, and it is noticeable that within the past ten years there have been practically no failures of reinforced concrete work. This is no doubt due to the greater knowledge which has been acquired by contractors in the construction of this particular kind of work.

The general public is gradually being educated into the many uses of reinforced concrete, and everyone is now well acquainted with this material, which is considered as a symbol of strength and durability. Its use for the construction of large warehouses and factories is well established, and its advantages in this respect need no longer be emphasised.

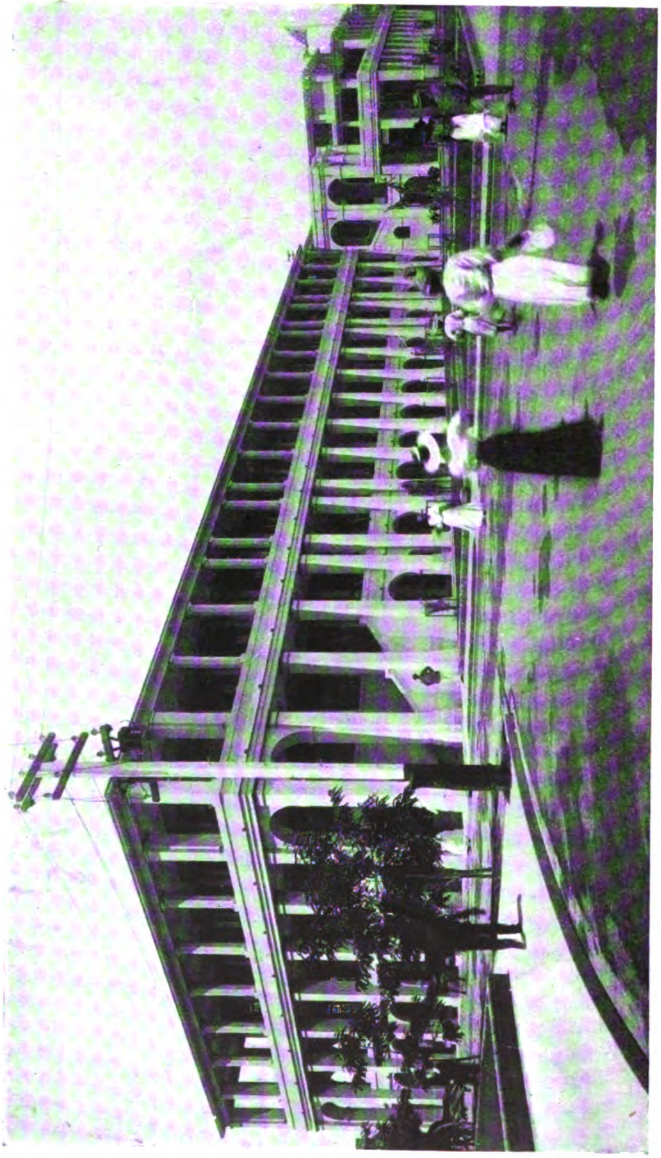
Its Multitudinous Uses.

An increasing number of water towers and reservoirs are being constructed throughout the country, and in fact reinforced concrete seems to have entirely monopolised this particular field of activities.



[R. C. Design by Edmond Coignet, Ltd.

The Second Tobacco Warehouse at Bristol in Course of Construction (1908).



[*Messrs. Nicholson & Corlette, Architects; R. C. Design by Edmond Coignet, Ltd.*

General Post Office and Treasury Building, Kingston, Jamaica: Built Twelve Years Ago.

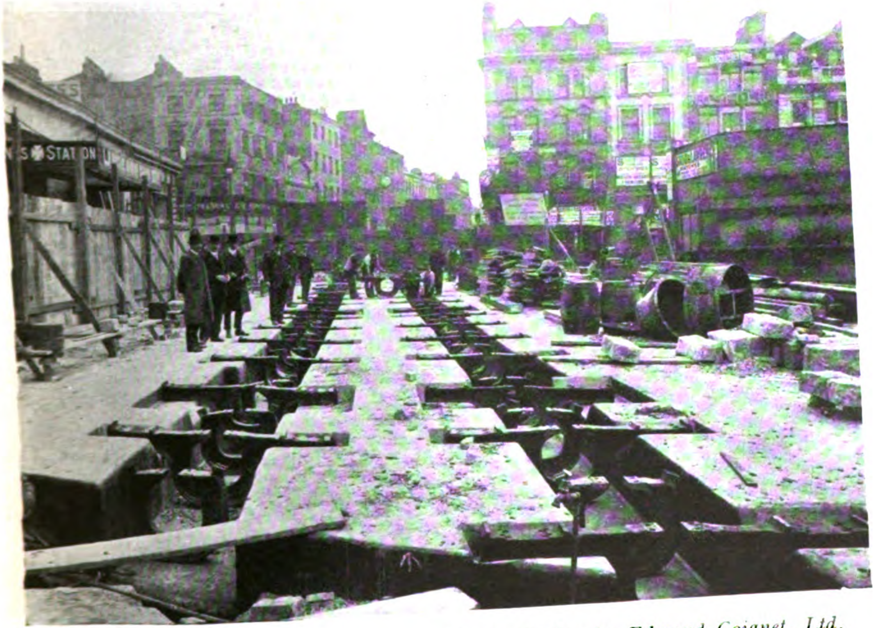
Gas and Electricity Works.—Gas companies and electricity works are constructing all their new bunkers and gantries in reinforced concrete, the principal advantage being that this material is not affected by the acid fumes which rapidly deteriorate steel construction. It also offers a greater resistance to fire, which is important owing to the possibility of spontaneous combustion where a large amount of coal is stored.

Reinforced concrete is also being used more and more for the construction of raft foundations on inconsistent ground, where it is capable of distributing very heavy concentrated loads over a very large area, and where formerly such foundations had to be constructed with a very considerable thickness of mass concrete which only increased the dead weight of the structure.

Marine Works.—Piles and sheet piles, although at first viewed with a certain amount of mistrust, have now become in general use for foundation works, river works, and marine structures. In the latter case the great advantage of reinforced concrete as compared with timber lies in the fact that it cannot be attacked by sea-worms, which have been known entirely to destroy heavy timber piles within a period of two or three years. It is well established now that the only precaution necessary in dealing with marine works is to provide for a cover of concrete of at least 2 in. wherever the work is exposed alternatively to wind and water.

Bridges.—Concerning the application of reinforced concrete material to bridges the Ministry of Transport is now dealing with a large number of schemes every year, and some of the bridges being carried out at present are of such importance that one can predict that reinforced concrete will be exclusively used in the future for bridges, except in certain cases where the spans have to be brought to the site ready for putting in position, such as in the case of the temporary bridge alongside Waterloo Bridge.

Silos.—For the storage of grain rein-



[*R. C. Design by Edmond Coignet, Ltd.*

One of the First Concrete Bridges in the Metropolitan Area : Built at King's Cross Twelve Years Ago.

[R. C. Design by Edmond Coignet, Ltd.

The First Jetty Constructed on the "Coignet" System. Built at Portland for the Admiralty Fifteen Years Ago.

forced concrete silos have entirely superseded the old-fashioned timber silos. A large number of structures of this description have been built in all our principal harbours. Here the question of fire-resistance, cleanliness, strength, and durability are very obvious, for reinforced concrete has established itself in a most definite manner to the exclusion of all other forms of construction. The same remark applies to the storage of cement, and as evidence of this we see that both in this country and abroad all modern cement works are constructing large cylindrical silos for this purpose.

Reinforced concrete is also finding a ready application in large culverts, water mains, and sewers, and is rapidly displacing masonry work and ordinary concrete. The difficulty of obtaining bricks and bricklayers is to some extent responsible for this new development.

Roads.—Finally, the most recent application of reinforced concrete is to be found in road work, where it is gradually becoming more and more used on account of the increasing weight of the traffic on many roads. In this respect the introduction of the new rapid-hardening Portland cements and aluminous cements has brought about a revolution in the speed of road construction, owing to the fact that it is no longer necessary to wait for several weeks before allowing traffic to pass over a new surface. Incidentally, rapid-hardening cements will undoubtedly considerably increase the development of reinforced concrete, especially where precast members are required and a large number of units can be rapidly turned out by using the same moulds.

Early Days of the Coignet System.

The Coignet system of reinforced concrete, which was already well known in France, was first introduced in this country in 1904, when the writer was appointed by the late Edmond Coignet of Paris as General Agent for the United Kingdom. Some of the earlier Coignet patents were already known in this country, but new patents were taken out dealing with improve-

Concrete Dwarf Wall at Herne Bay.

ments, and more especially with a new method of making the reinforcement of beams by means of groups of bars, the ends of which were bent up in an angle of 45 degrees and hooked over a top bar to take the shear. The idea was to produce beams of uniform resistance to the bending moments and to the shear with a minimum amount of steel and concrete. This method has been very largely used not only in this country but throughout the world, as it is more scientific and more economical than the old method of straight bars and stirrups which is still used to a certain extent for lintels.

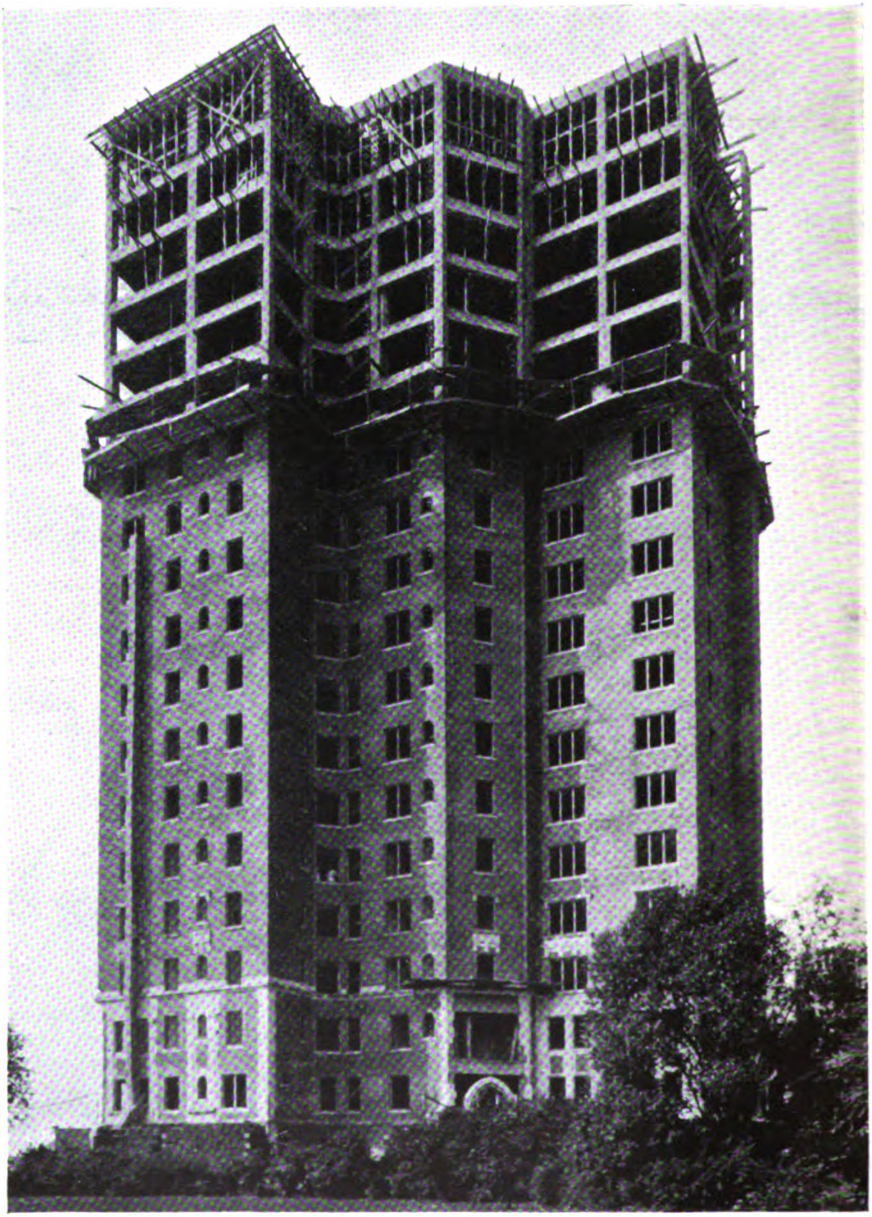
Improvements were also introduced in the method of constructing pillars by breaking the joints at each floor level and providing joint bars. By the older method the bars used to be carried up for a considerable height through two or three of the floors. Improvements were also made in the method of making links or stirrups in the beams and also in the pillars. It was found, for instance, that instead of making a difficult twist or knot in the case of $\frac{3}{16}$-in. or $\frac{1}{4}$-in. stirrups in beams it was quite sufficient to bend these ends over a top longitudinal bar, which is the method adopted to this day.

The reinforcement of piles was also modified from a continuous spiral to individual links, which were found easier to make and more efficient. This method was also adopted for the construction of the links in pillars, although in many cases the spiral reinforcement is still employed, more especially when it has to be taken into account for the strength of the pillar in accordance with the recent Regulations.

Dealing further with the question of improvements of the patents, a new kind of sheet pile was introduced called the "Coignet-Ravier Wing Piles," which may be described as a pile of rectangular section fitted on each lateral side with wings in reinforced concrete or side panels to retain the earth, the main body of the pile only being driven into the solid ground and acting as a beam supporting the side panels or wings, the main body of the pile itself being tied back at suitable points of its height by land ties and anchor plates.

One of the most important contracts carried out on the Coignet system, as well as one of the earliest, was the construction of the second Tobacco Warehouse for the Bristol Corporation, in 1908, under the supervision of the late Mr. W. W. Squire. This large building was approximately 200 ft. long by 100 ft. wide and over 90 ft. high. It contained nine floors, and the foundations required about 700 piles approximately 50 ft. in length. An important patent action was fought in connection with these piles, and the matter was taken as far as the House of Lords, where it was held definitely that the method of construction of the Coignet piles was not an infringement of any other existing patent.

In 1908 the late Mr. E. Coignet transformed his business into a limited liability company, of which until his death he remained the Chairman, the writer being appointed Managing Director.



Detroit Towers Apartment House, Detroit.

(*Reinforced Concrete Frame :* 18 *Stories High.*)

Concrete in the United States during the past Twenty-one Years.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.
(*Syracuse, New York.*)

In this "Concrete Age" it is difficult to realise that little more than twenty-one years ago concrete was just becoming recognised as a satisfactory building material. Although before that time concrete had been extensively used for foundations and sidewalks, and a few structures of reinforced concrete had been built, yet it was looked upon with some suspicion by engineers and architects.

The Early Days.

It takes time and education to introduce a new building material. The average man was rather afraid of a composite material that depended for its strength and durability on the properties of its constituents and their correct proportioning and efficient mixing in the field. It was felt that there were too many sources of possible failure, and that too much reliance was placed on the workman, ignorant in most cases of what constituted "good concrete." This distrust could only be overcome by educating the people in concrete, and the last twenty-one years has seen a great educational campaign carried on in this country.

We do not yet know all about concrete, but our education is still going on and in the last three or four years particularly we have made great strides forward to a better understanding of what is "good concrete" and how it should be made.

Enormous Growth.

Development of a building-material industry can be considered along three lines, namely, increase in volume, diversity of structures for which the material is used, and improvements in quality and methods of manufacture. When these three lines are developing together then real progress is being made, and this is the case with the concrete industry. We will consider these three lines of development separately.

The wonderful growth in volume can best be realised from a study of the output of cement during this period of time. In 1904, 26,500,000 barrels of cement were produced, a barrel weighing 376 lbs. At the close of 1925 it is estimated that about 160,000,000 barrels will have been manufactured during the year, or an increase of 600 per cent. in twenty-one years. In the same period the output of structural steel has increased only about 30 per cent., while brick and lumber have remained practically stationary.

It is obvious, therefore, that concrete is rapidly displacing other materials in construction work. This is true, since for many structures and parts of structures concrete is now the only material considered. A little over twenty-one years ago the United States imported more cement than it manufactured; to-day it manufactures more than all the other countries of the world combined, mainly for home consumption, only about 2 per cent. being exported.

Where does this immense production of cement go? This brings us to the consideration of the diversity of structures. About 24 per cent. is consumed in concrete highway and city paving construction, 25 per cent. in public and commercial buildings, 21 per cent. in farm buildings, 16 per cent. in dwellings, sidewalks and driveways, 8 per cent. in railways and public works, and 6 per cent. in manufactured pipe and miscellaneous uses.

These proportions show two outstanding and remarkable facts, namely, the tremendous growth of concrete for use in road and city paving works and for farm structures, the two combined taking nearly half the total output of cement. The concrete industry's greatest progress has been in road construction.

All-Concrete Roads.

The years 1902 to 1912 saw the development of the motor vehicle, and a natural consequence was a demand for better highways.

Since 1912 the automobile has been brought within the means of almost every family, and this new means of transportation so outstripped the improvement in road construction that a national demand arose for highways built primarily for motor traffic. In an effort to find a surfacing material that would stand up under this type of traffic, engineers turned to concrete. About 1910 experimental roads were laid down on a large scale, and the extensive tests made on them were so great a success that concrete is now the dominating material in the construction of main highways. Twenty-one years ago less than 50 miles of concrete road had been built. To-day about 38,000 miles of roadways 18 ft. wide have been completed or are under construction and 6,000 miles are being built yearly. Its construction is not yet perfect, but research work on materials and proportioning and improvement in design and construction are bringing the concrete road nearer to perfection every day.

The Lincoln Highway, stretching 3,000 miles from New York to San Francisco, has one-fifth of its surface paved with concrete. The Pacific Highway, from Mexico to Canada, has already half its length paved with concrete, including one unbroken stretch of 135 miles. Concrete paving has been found desirable not only for highways but for city streets and alleys, the equivalent of over 9,000 miles of city streets 30 feet wide having been laid.

Concrete on the Farm.

The next outstanding development of the concrete industry is its use on the farms. The farmer is naturally a conservative person and needs educating to the use of new and better methods. The American Portland Cement Association, together with the Agricultural Colleges and the U.S. Department of Agriculture, through their research work and dissemination of the knowledge gained, have provided this education.

To-day there are over 150 common uses for concrete on the farm. The improvement in silage and its safety against fire by using concrete silos, the saving in feed by using concrete feeding floors, and the saving in the essential elements of barnyard manure by building leak-proof concrete manure pits, alone have saved many thousands of dollars for the farmers, besides contributing to the conservation of natural resources. There are nearly half a million concrete silos in the country to-day.

Building Construction.

The greatest use for reinforced concrete is in the building industry. Twenty-one years ago less than 50 reinforced concrete shops and factories had been built. To-day it is used in one place or another in almost every building, and many buildings are erected exclusively of this material.

The development of the concrete building has been due to the demand for fireproof structures. The use of wood-frame buildings resulted in an immense yearly fire loss, amounting to about 4 dollars 75 cents per head of the population, or about fifteen times the per capita loss in England. In the last twenty years the fire loss has been about one-quarter of the value of all new building during that time, with an annual loss of life of 15,000 to 20,000. It will be seen then that the development of the fireproof concrete building has been a vital necessity in this country; now in the majority of cities the use of concrete for fireproofing is compulsory in buildings over a certain height.

As a material for fireproofing structural-steel frames, concrete has almost entirely replaced the hollow tile. As dead weight is an important consideration, cinders or clinker are now largely used to obtain a light-weight concrete.

The reinforced concrete building has been almost entirely developed within the past twenty-one years, and has now reached a high state of perfection. At first it developed along the lines engineers and architects were most familiar with, namely, beam and girder construction.

"Flat Slab."—For buildings designed for heavier live loads a great improvement on this type of construction was the introduction of "flat slab" floors, which have created a distinctively concrete type of structure, employing the particular properties of concrete which do not exist in other materials.

It was at first looked upon with some suspicion, being a very radical change and, because of the absence of exact scientific knowledge of the behaviour of flat plates of concrete, empirical formulæ had to be used in its design. However,

Army Supply Base, Brooklyn.

(*Flat-slab design. The building in the foreground is the largest in the world, measuring 980 ft. by 206 ft. by 8 stories high and basement. The roof was poured 4 months after the contract was signed.*)

numerous floor tests on completed buildings demonstrated its great strength and greater factor of safety over other types of floor, and it grew rapidly into favour. Now it is always given the first consideration in the design of a building when the live load is 150 lbs. or more per sq. ft., and it is safe to say that 90 per cent. of the concrete factories and stores are designed on this system. The "flat slab" floor is the most noteworthy advance that concrete has made in the building industry.

For buildings with lighter floors the development has been towards long-span joist construction with a filler of metal, terra-cotta tile, or gypsum block to reduce the dead weight and save unnecessary concrete. This construction has been mainly developed by manufacturers of the different kinds of tile or filler. The development of metal lath has made possible the use of concrete for light-weight fireproof floors and partitions.

Some Big Concrete Buildings.—The war gave a big impetus to reinforced concrete construction in buildings, since structural steel was difficult to obtain and high in price. Some of the largest concrete buildings in the world were built during that time. The Brooklyn Army Supply Base consists of two parallel buildings, each 980 ft. long and 8 stories and basement in height, the width of one building being 306 ft. and the other 200 ft. It is interesting to note that the roofs of these buildings were completed in a little over four months from the signing of the contract, a tribute to the speed with which concrete buildings can be erected.

At first reinforced concrete was confined to comparatively low buildings, but in the past few years concrete buildings of 16 stories and over are not uncommon. The highest concrete building in the world is the United Brethren Building at Dayton, Ohio, 22 stories high and 274 ft. above the pavement. To show that concrete can compete in cost, it is stated that this building was built for 25 per cent. less cost than the estimate on a steel structure. Another interesting high building is the 18-story Detroit Towers Apartment House.

The American Furniture Mart, an office, showroom and exhibition building just completed in Chicago, is 16 stories high with a floor area of 1,500,000 sq. ft. The main difficulty with high buildings has been to keep down the size of the columns, and this has been done by using hooped columns and a richer concrete mixture so that they are little if any larger than fireproofed structural steel columns would be.

Surface Treatment.

In the method of finishing concrete surfaces great progress has been made, so that it is no longer necessary to cover up the concrete frame with brick or stone. The use of electric rubbing machines and the exposing of selected aggregate by removing the surface coat of cement has given surfaces equal to and more durable than those of natural stones.

Many fine buildings with an exterior

entirely of concrete have been erected in the heart of cities, comparing favourably with the buildings around them. Notable amongst these are the 18-story Hide & Leather Building, New York, and the 19-story Medical Arts Building at Dallas, Texas.

Together with the progress of reinforced concrete has come a gradual recognition by architects of the wonderful possibilities of this material for decorative purposes, resulting in a great improvement in the architecture of concrete buildings and in the development of a new technique in the handling of concrete. Not only exterior but interior architecture also is being carried out successfully in concrete by a few pioneer architects.

Sculptors, too, are turning their attention to concrete as a desirable material for their use, since while it is everlasting when plastic it can be moulded as desired, and it can be finished in any desired texture to suit its surroundings. The " Fountain of Time " in Washington Park, Chicago, containing nearly a hundred figures, would never have been built owing to prohibitive cost if it had not been for the sculptor's faith in the possibilities of concrete. Mr. Lorado Taft, the famous sculptor, in an address on " A New Art of Concrete," says, " It seems to me that we are on the verge of one of the greatest developments of American art."

Not only for the large buildings but for the small home concrete is being used extensively. The concrete house has been developed mainly in the southern part of the country, because it is particularly adaptable for the low Spanish type of architecture favoured in warmer climates. While the poured *in situ* method is used to some extent, the use of concrete block and tile finished with cement stucco is more common.

Public works form naturally a large field for concrete construction. The rapid growth of the cities demands ever-increasing outlay on bridges, reservoirs, dams, sewage disposal structures, and hydro-electric plants, and concrete plays the major part in their construction. Sidewalks and driveways are universally built of concrete, to the almost total exclusion of other materials.

Bridges.

Concrete bridge construction has made rapid strides in the past few years, and this material now leads all others for this work. The artistic appearance, adaptability, permanence and low cost and maintenance of concrete have greatly advanced the art of bridge building. At the present time about 75 per cent. of all the new bridges are built in concrete, which means practically all bridges except the very small ones and those where it is necessary to use steel by reason of special local conditions.

Starting with quite small spans, spans of 200 to 400 ft. are now not uncommon. Many beautiful structures have been built, often being chosen as memorials. Amongst the noteworthy bridges are the Cappelen Memorial Bridge at Minneapolis, with a clear centre span of 400 ft. (the longest in the country), and the Fairmount Memorial Bridge, with three spans of 250 ft. each.

The Tunkhannock Viaduct, built by the D. L. & W. Railway, in Pennsylvania, is the largest structure of its kind in the world, and a wonderful example of the artistic possibilities of concrete for bridge construction. It is 240 ft. high and 2,375 ft. long, consisting of ten semicircular arches of 180 ft. span and two arches of 100 ft. span, and contains 165,000 cubic yards of concrete.

In the construction of dams, the development of reinforced concrete has originated two entirely new types, the hollow dam and the arch dam, both of which show great economy over the usual gravity type. The Wilson Dam, now nearing completion at Muscle Shoals, Alabama, will be the largest masonry dam in the world, containing 1,400,000 cubic yards of concrete.

Products.

The manufacture of concrete products is a fast-growing industry, and " something new in concrete " is being developed almost every day. Blocks and tiles are the leading industries, which have increased 1,000 per cent. during the past six years, the present yearly production being about 500,000,000 pieces.

Concrete pipe is another widely manufactured product, and it is rapidly replacing the terra-cotta tile pipe formerly used for sewers, field drains, and irrigation purposes, and is beginning to compete with cast-iron pipe for water lines. In California alone over 25,000 miles of concrete pipe have been used in the construction of irrigation systems.

Cast stone is one of the most valuable of products. It can be made in any desired texture and colour, and is preferred by many architects to natural stone. One of the largest factories produces about 25,000 tons per year, and its business is steadily growing.

Concrete brick is produced to the amount of over 200,000,000 a year. Concrete staves have a large sale for the construction of silos. Another favourable field for concrete product manufacturers is in telephone and telegraph poles, fence posts, and lighting standards.

It is impossible to mention all the products that are being manufactured as they are so numerous, but the extent of their popularity can be judged from the fact that there are over 6,000 firms engaged in their production.

Use of Machinery.

The question now remains as to whether the quality and methods of manufacture of concrete during the past twenty-one years have kept pace with its immense growth in volume and diversified usage.

Concrete, being a product of the field and not of the factory, is much more difficult to control and keep at a definite standard of quality. To eliminate human errors, carelessness, and ignorance, and to reduce the cost of production, machinery has been introduced and improved until now concrete may be considered a machine-made product. Practically all the improvements in the methods of mixing and placing concrete and in building forms have originated in this country. Of necessity the improvement in machinery and the growth of the industry have developed together, the one being dependent on the other.

Concrete-mixing machines are now universally used, however small the work, and the type and size can be chosen for the particular work desired. The proportioning of the aggregate can be controlled by steel batch-boxes attached to the mixer feeding bins, which can be adjusted to the exact proportions desired and eliminate hand guess-work.

The increase in the size of concrete structures has required central mixing plants, resulting in the development of distributing machinery. Steel towers and chuting equipment enable concrete to be placed economically over wide areas, and it can be transported long distances by means of trucks, cableways, pneumatic methods, etc. In the modern central-mixing plant the aggregate is handled from the stock-pile by derrick and clam-shell into the feeding bins, passing through the batch-boxes, where it is proportioned, into the mixer; the cement is taken by conveyor from the storehouse to the charging platform; the amount of water is controlled by a measuring tank on top of the mixer; the concrete is dumped into a hopper, shot to the top of a tower, and distributed where required by chutes. Five or six men can take care of all these operations until the concrete is deposited. Compare this with the labour required to perform these operations by hand! Also, the concrete has a definite and uniform standard of quality.

Formwork.

The building of formwork has also improved until now there are recognised standard methods of construction. The introduction and continual improvement in steel forms for walls, floors, silos, sewers, tunnels, bridge centres, etc., is resulting not only in economy but in better workmanship and surface finish. Not to be forgotten are the many patented specialities such as form clamps, wall ties, adjustable shores, inserts, reinforcing steel ties, and spacers.

Quality of Concrete.

Coming now to theoretical considerations, what has been the progress in our knowledge of what constitutes "good concrete"? Twenty-one years ago about all we knew was that concrete should be mixed using cement, sand, and stone in the proportions of 1 : 2 : 4 or 1 : 2½ : 5, or in some other nominal amounts, water being added as desired, in order to give approximately certain strengths. This condition lasted for a number of years without much progress being made, and it is only recently that we have made any appreciable advance in our knowledge.

Cement has always been given the most attention; its improvement has been continuous until it has reached a definite and uniform standard of quality. The importance of the grading of aggregate, and more especially of the ratio of water used in mixing to the volume of cement, although suspected has been neglected until the past few years. Valuable information on the subject has been given to the world recently by Mr. Duff Abrams, the Director of the Structural Materials Research Laboratory, which is devoted entirely to experimental work on concrete and cement. More than 100,000 tests at this laboratory have established the "Water Ratio Theory," which is that for, "given materials and conditions of manipulation, the strength of concrete is determined by the ratio of the volume of mixing water to the volume of cement so long as workable mixtures are obtained." In other words, the proportion of cement to aggregate, the consistency of the concrete, and the grading of the aggregate, affect the strength only in so far as they determine the water ratio, provided the aggregates are clean and durable.

The last report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete recommended that concrete of desired strength should be specified, instead of stating definite proportions for concrete mixtures. To conform with this recommendation it becomes necessary to know how to proportion mixtures to obtain a specified strength, and by means of the "water ratio theory" this can now be done.

To be able scientifically to proportion and control concrete, using available materials, to obtain a desired strength, is a great step forward in the progress of the concrete industry. Simple field equipment has been devised which, with the aid of charts and tables, enables the field engineer to design a concrete mixture in a few minutes for any samples of fine and coarse aggregate.

Field testing has of late been given more attention than formerly, slump and compression tests being made frequently from samples taken from the forms so that the concrete can be kept up to the standard required.

Other important investigations that are under way will increase our knowledge of temperature and shrinkage stresses, and the "flow of concrete" under constant load. Experiments on a large scale or on actual structures are always more convincing than those made in the laboratory. The construction of an arch dam 60 ft. high is being commenced, purely for experimental purposes; ultimately it will be raised to a height sufficient to cause failure.

The problem of winter construction is now receiving much notice in an effort to make concrete construction an "all the year round" instead of a seasonal industry in the northern part of the country. It has been demonstrated in several buildings constructed during the winter that concrete can be poured safely and economically in very low temperatures provided proper precautions are taken.

Design.

The last consideration is that of the design of reinforced concrete structures. Being more practical than theoretical, Americans have given more attention to reducing the cost and improving the quality of concrete than to design methods. These are much the same as they were twenty-one years ago, and improved methods come slowly.

The Future.

The industry in the next few years should show a steady growth, developing particularly in the fields of road and house construction and in the manufacture of concrete products.

The amount of concrete going into the construction of buildings and engineering works probably cannot increase much except as the demand for these structures increases, but there will be great improvement in quality and architectural treatment.

The introduction of rapid-hardening Portland cement opens up a new field of development for the concrete industry, and if it is produced on a large scale the next few years may see the greatest progress yet made in the concrete industry.

PROGRESS DURING A QUARTER OF A CENTURY.

A Record of what has been done since the Inception of the Industry.

In the following pages we give a brief history of, and a list of reinforced concrete works carried out by, most of the principal firms engaged in the concrete industry. The first reinforced concrete structure was built about twenty-five years ago, and this journal has been in existence for nearly the whole of that period. Every effort has been made to make this section as complete as possible, as we think it will be of more than passing interest; it will, in fact, be the only record of the early days of the industry, from which future generations will be able to see what remarkable progress has been made in such a short space of time. For convenience of reference the firms are arranged in alphabetical order.

Wm. Airey & Son, Ltd.

During the war the firm carried out three very large gun-testing ranges at Meanwood, Melton Mowbray, and Birmingham. Other important works in reinforced concrete include raft foundations, coal bunkers, turbine beds, and wharf walls at the Leeds Electric Power Station; a factory at Selby for Fletcher & Son, Ltd.; and reservoirs for the Acton Hall Colliery Company.

During the past three or four years the firm's concrete activities have mainly been concerned with concrete houses, erected on their "Duo-Slab" system; large schemes comprising many hundred houses each have been carried out at Leeds, Edinburgh, Swansea, and elsewhere.

[Wm. Airey & Son, Ltd., Contractors.

Concrete Houses on Meanwood Estate, Leeds.

The Allen Construction Co.

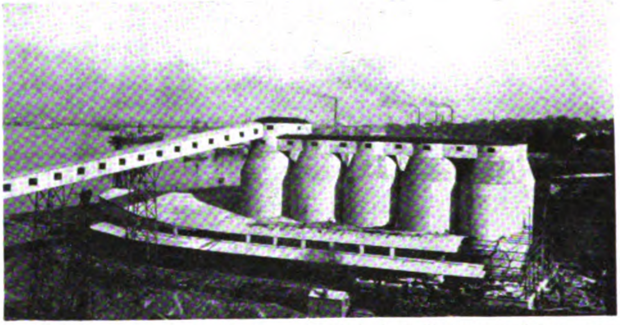
Commenced business in 1900. Amongst the works carried out may be mentioned: General contracts—Kodak Buildings, Kingsway, London; Alhambra Theatre, Glasgow; Shipbuilding Co.'s office block, 120 houses, streets, etc., Alloa. Special flooring contracts—Glasgow Western, Arbroath, and Stoke-on-Trent Infirmaries; Glasgow Royal Samaritan and Nottingham Children's Hospitals; Govanhill, Glasgow, and Arbroath baths; various schools, office blocks, and institutions. Designing—reinforced concrete for various picture houses, theatres, hospitals, office blocks, etc.

[Sir J. J. Burnet, A.R.S.A., & Partners, Architects; Allen Construction Co., R. C. Designers and Constructors.

Alhambra Theatre, Glasgow.

Anglo-Danish Concrete Construction Co., Ltd.

Started business in 1912 as reinforced concrete engineers and contractors under the title of "F. Moehl." The firm has designed and carried out reinforced concrete constructions for many cement manufacturers in this country, this work mainly consisting of chimneys, silos, foundations, clinker stores, slurry basins, loading jetties, etc. Reinforced concrete constructions have been carried out at glass works, chocolate factories, steel works, colour works, and for works abroad (including a reinforced concrete floating dock which at the time it was built was probably one of the first in the world), wharves, gantries, jetties, bridges, grain elevators, etc. Up to the present the firm has built more than 300 chimneys in reinforced concrete in different parts of the world.

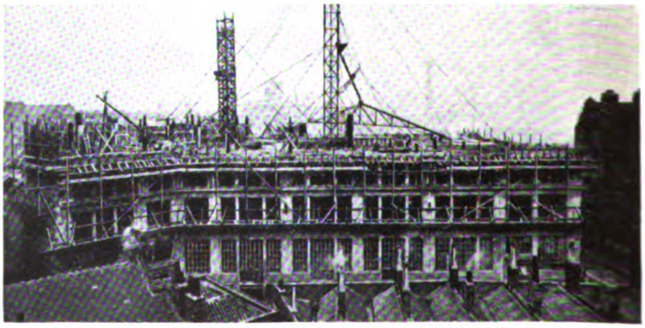


[*Anglo-Danish Concrete Construction Co., Ltd., R. C. Designers and Contractors.*

Cement Storage Silos.

Sir William Arrol & Co., Ltd.

In 1919 it was decided to extend and develop this well-known firm's business in the design and construction of reinforced concrete work, and to enlarge the outside organisation for this branch. Mr. T. B. Shore joined the Board as Director responsible for reinforced concrete construction, and in the past few years many important contracts, embracing a variety of special engineering problems, have been carried out.



[*Sir William Arrol & Co., Ltd., Contractors.*

Amalgamated Press Building, London.

Among the most important works carried out by the reinforced concrete department of the firm may be mentioned the new building at Southwark for the Amalgamated Press, Ltd. (£150,000); bleachworks at Anchor Mills, Paisley—including bridge over River Cart (£150,000); two transit sheds at King George V. Dock, for the Port of London Authority (£600,000); foundations for two transit sheds for the Manchester Ship Canal Co. (£50,000); 3,500 ft. of wharves, two transit sheds, 12,000-ton silo granary, 20,000-ton silo granary, and 4,500 piles 54 to 61 ft. long, for the Royal Edward Dock Extension at Avonmouth — now under construction (£750,000); depository, warehouse, and garage for Messrs. Wylie & Lochhead, Ltd., Glasgow —under construction (£40,000); power houses, bridges, weirs and surge tanks, for the Lanarkshire Hydro-Electric Power Co. —under construction (£200,000); Bexley Heath By-Pass Road, 2 bridges over the Southern Railway, and 2 river bridges (£45,000); bridge at Carlton (£40,000). So far the contracts of the Reinforced Concrete Department amount to over £2,250,000.

Frank Bevis, Ltd.

Founded in 1820, and has carried on business continuously since that date. The principal reinforced concrete works carried out are as follows: *Quays, Wharves, and Jetties.*—Southampton Town Quay (370 ft. by 34 ft., carrying railways and cranes); Portland Harbour (three large jetties and approach for torpedo destroyers; two jetties for oil fuel; and the camber jetty); Southampton

Coaling Wharf (dolphins and jetty); East Cowes, (jetty for goods traffic); Rochester Coaling Wharf (340 ft. long carrying railway traffic and 100-ton cranes); West Cowes Jetty (for goods traffic); Haslar Submarine Depot (comprising jetty 900 ft. long, approaches, dolphins for floating dock, and a further jetty 400 ft. long); Barking Jetty; Rochester Coaling Wharf extensions; Woolston (four wharves and jetties); Portland Harbour (large jetty and approaches and dolphins for floating dock); Portland Breakwater (large jetty and approaches); Erith Oil Works jetty (300 ft. long and approach bridge, conveyor tunnel and machine rooms under jetty); new head to Town Quay, Southampton; Portsmouth Customs landing stage; Ryde Pier, for Ryde Pier Company; Rudmore Wharf, Portsmouth; South Parade Pier, Southsea; North Wall Jetty, Portsmouth Dockyard (the first jetty constructed in reinforced concrete for Admiralty); dolphins at Langstone Harbour. *Road Bridges*—Blackwater Road Bridge; Westend Road Bridge; Virginia Water Road Bridge (over railway, 70 ft. span); St. Helens Road Bridge; Bersted Bridge (Bognor); Alver Bridge (Gosport). Reservoirs at Guildford, Lytcheet Maltravers, Yew Hill, Hedge End, Pidding-hoe, Ryde gas-holder tanks. Water Towers at Fereham and East Grinstead (91 ft. high). Buildings, Floors, etc., at Woolwich Dockyard; Portsmouth Gunwharf; White Star Line stores, Southampton; Southampton Corporation Bakery; Eastleigh Police Station; Regent Cinema, Portsmouth; Cinema at Cowes; Portsmouth Swimming Club; Camber Docks, Portsmouth. Sea Walls and Defences at Weymouth, Ramsgate, Roedean, Portsmouth Gunwharf, Cowes, Southsea, Seaton, Portsmouth Docks, and Fareham. Coal Silos at Rudmore Wharf, Portsmouth; Portsmouth Co-operative Society; feeding silos, Crofton, Hants; and for Fraser & White, Portsmouth. Foundations to Buildings and Piling at Woolwich Arsenal; Weymouth Pier Pavilion; Shanklin gasholder; Southampton Gas Works; Cowes machine shops; Weymouth schools; Ryde Gas Works retort; Newport corn store; Aircraft Factory at Cowes; J. S. White & Co., Ltd., Cowes. Sewer Outfall at Freshwater (500 ft. long, 4 ft. 6 in. diameter).

[*Frank Bevis, Ltd., Contractors.*

Reinforced Concrete Jetty.

Henry Boot & Sons (London), Ltd.

Founded 1888. Messrs. Henry Boot & Sons are one of the largest contractors in the country, and have recently made a speciality of the construction of concrete houses in addition to larger structures. The annual turnover of the firm is £1,500,000, and among the firm's large contracts during recent years may be mentioned Calshott Seaplane Station (£338,000), factory at Canning Town for British Glass Industries, Ltd. (£600,000), factory at Charlton for the United Glass Bottle Manufacturers, Ltd. (£218,000), Gravesend-Strood road for the Ministry of Transport (£300,000). To date the firm has completed about 7,000 concrete houses in various parts of the country on its special pier-and-panel system, including 1,500 at Leicester, 1,300 at Birmingham, 1,000 at Sheffield, 780 at Bradford, 600 at West Bromwich, 438 at Bilston, etc. The firm makes a special point of rapidity of house building, each scheme of 1,000 houses being completed in two years. During the war the firm carried out War Office contracts in Yorkshire alone to the extent of over half-a-million pounds, including about a thousand military buildings ranging in size from 60 ft. by 20 ft. to 210 ft. by 24 ft., all built of concrete. Some of the concrete houses built by Messrs. Boot are illustrated elsewhere in this issue.

The Bristol Concrete Co., Ltd.

Formed in 1920. The activities of the Company are directed to all classes of pre-cast concrete, and many housing schemes have been carried out with the products of the Company, principally those at Long Ashton, Axbridge R.D.C., Shepton Mallet R.D.C., and recently Yeovil Corporation's

[*Precast by the Bristol Concrete Co., Ltd.*

A Concrete Staircase.

scheme of 50 houses at Grass Royal, Yeovil. Over 25 miles of fencing, kerbing, and paving have been supplied for various County Councils, local authorities and others. Success has been experienced with specialities such as cable covers and joint boxes, direction posts, etc. In 1924 the volume of trade in partition slabs necessitated the opening of a branch works devoted almost exclusively to the manufacture of these goods. The Company has secured Post Office contracts for the supply of marking posts and concrete kiosks.

Cambridge Artificial Stone Co., Ltd.

Registered in 1919 for the purpose of manufacturing concrete blocks, slabs, etc., and commenced business employing only six men. A few months after commencing business orders had been secured for concrete blocks and slabs for upwards of 250 houses (of which Messrs. Kennard & Kennard were the architects) in the Cambridge area. Numerous houses have been erected of special faced blocks at Cambridge, Shelford, Buntingford, Chesham, Melbourn and other places. The firm also manufactures partition slabs and breeze building blocks, and the weekly output is now many thousands of yards super.

Two years ago "Casco" stone was placed on the market, and on one contract of 50 brick houses all the window sills are of "Casco" stone, while on the same job the whole of the bay windows are made in this stone. At the present time the firm is supplying the stonework (such as Gothic arches to doors and windows, tracery windows, copings, etc.) for a chapel, as well as for a shop front. The Company has supplied cast stone for Lloyds Bank, Haverhill; Port of London Authority; Bury St. Edmunds housing scheme and Playhouse; Cambridge housing schemes; shop front at St. Ives; Newmarket housing scheme; Spalding Grammar School; extensions to cinemas, etc.

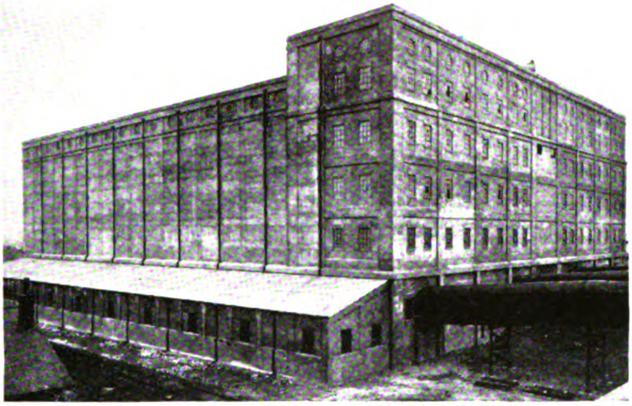
British Reinforced Concrete Engineering Co., Ltd.

Formed in 1908, and continued in a small way until 1911, when the firm was reorganised on broader lines in order to deal with the manufacture of reinforcements as well as the preparation of designs for reinforced concrete constructions. The Company now has a head office in Manchester, branch offices in London and several provincial towns, and works in Manchester. New premises are at present in process of construction in Stafford, and the head office and works of the Company will be located there early in 1926.

The Company has prepared designs and supplied the reinforcements for a large number of important structures of all kinds, including grain elevators, coal bunkers, coal

[*Messrs. Wm. & Segar Owen, Architects ; B.R.C. Reinforcement.*

Bridge over Lymm Dam, Cheshire.



[*Reinforcement by the British Reinforced Concrete Engineering Co., Ltd.*

Grain Elevator at King George Dock, Hull.

washeries, water towers, reservoirs, sewage tanks, bridges, culverts, retaining walls, jetties, factories, office buildings and warehouses.

The grain elevator buildings include the building at King George Dock, Hull, which is about equal in size to reinforced concrete elevators at Manchester and Glasgow, these being the three largest elevators in the country.

Bridge constructions have been carried out in various parts of the country; these include Longford Bridge and Warwick Road Bridge, Stretford; Deeps Bridge, Wexford; Stanhope Bridge, Peebles; Crownhead Bridge, Stobo; Pontneathvaughan Bridge, South Wales, etc. An interesting example of this work is Summerhill Bridge, Dublin, built for the Midland & Great Western Railway of Ireland. This bridge spans two lines of railway track, and was built of pre-cast sections. The road over the railway is traversed by tramway traffic. The demolition of the old bridge and the placing in position of the pre-cast sections of the new bridge was carried out so expeditiously that the traffic over the bridge was interrupted for one night only.

Recent water towers erected are the Armthorpe Water Tower, Doncaster, height 75 ft., capacity 250,000 gallons; and at Ossett, height 105 ft., capacity 200,000 gallons.

Buildings of the warehouse class include the largest reinforced concrete building in Great Britain, constructed by the Mersey Dock & Harbour Board at the New Gladstone Dock. This structure is 1,500 ft. long by 150 ft. wide and 3 stories high, and built entirely of reinforced concrete.

The reinforcements manufactured and supplied by this Company are known as B.R.C. reinforcements, their principal features being the patented B.R.C. stirrup, which is a grouped stirrup, consisting generally of eight separate stirrups welded together and applied as one unit; and B.R.C. fabric, an electrically-welded steel wire fabric.

The Company are the originators of road reinforcement, and this use of reinforced concrete has advanced so rapidly during the last few years that it is now a generally-accepted principle of road construction.

Christiani & Nielsen.

Founded in 1904. The firm, which carries out all kinds of reinforced concrete work, preferably to its own design, started its activities in Copenhagen, but has since spread to several other countries, having offices at Copenhagen,

[*Christiani & Nielsen, R. C. Designers and Contractors.*

Breakwater at Helsingborg, Sweden.

London, Stockholm, Oslo, Paris, The Hague, Hamburg, Rio de Janeiro, Buenos Aires, and Melbourne. Being one of the pioneers of reinforced concrete engineering, the size of the firm increased as the qualities of reinforced concrete became generally acknowledged, and reinforced concrete bridges and factory buildings have been built in all parts of the world. The firm has gradually developed reinforced concrete in connection with marine work as its speciality, and has carried out contracts for the construction of harbour works in England, Denmark, Norway, Sweden, Germany and Holland.

Some of the more prominent of the contracts undertaken to the firm's design are the following: Reinforced concrete jetty in the Thames for the County of London Electric Supply Co., Ltd.; factory buildings at Erith, Kent, for the Erith Oil Works; reinforced concrete foundations for Tilbury Urban District Council; reinforced concrete filters for the Metropolitan Water Board, London; breakwater and harbour work at Helsingborg, Sweden; bridge across the Dalelv, Sweden; bridge across the Aire, France; harbour work at Copenhagen, Denmark; bridge across the Alster, Hamburg; bridge across the Pumba, Brazil; 2,000-ft. railway bridge at Petrograd; bridge across the Murray, Australia; bridge across the Fnjoska, Iceland; factory building and business premises, Gold Coast, British West Africa; and harbour works at Delfzijl, Holland.

Edmond Coignet, Ltd.

Commenced business in this country in 1904 (some further notes on the early history of this Company are given in an article by Mr. G. C. Workman, Managing Director, elsewhere in this issue).

The firm designed several large buildings in London for H.M. Office of Works, including the Western District Post Office in Wimpole Street; the Money Order Department at Holloway, the reinforced concrete of which was carried out in the short period of nine months, for which the contractors were paid a premium of £2,000; and the Science Museum at South Kensington built during the war, the size of which may be gauged from the fact that no less than 1,300 tons of mild steel bars are used in the construction. Several works were carried out for the Admiralty in the early days of the firm, including a 500-ft. jetty at Portland and a new Joiners' Shop at Portsmouth Dockyard. Coignet piles were used for foundation work at the Dundee Generating Station; for underpinning the West Pier at Newhaven; and for a wharf for the Cork Harbour Commissioners.

In 1910 it was decided by the Crown Agents for the Colonies to use reinforced concrete for the construction of new public buildings at Kingston, Jamaica, on account of its earthquake and fire-resisting properties, and the reinforced concrete design of these buildings was entrusted to the firm. In 1912 the Company made the working drawings for transit sheds, warehouses, underground passages, etc., for the Dock Extensions at Buenos Aires, the total cost of which was about £5,500,000, and the cost of the reinforced concrete work about £1,500,000.

In 1923 the firm designed what is believed to be the first important reinforced concrete bridge in the Metropolitan area, namely, a bridge at King's Cross for the Metropolitan Railway. Immediately after this working drawings were made for the offices of the Metropolitan Railway at Baker Street Station. One of the first bow-string bridges in this country was that designed for the Powell Duffryn Collieries at Bargoed; it has a span of 60 ft. and a width of about 27 ft.

A large number of bunkers have been designed by the firm, including an elevated coal bunker with a total height of over 100 ft. for the Wombwell Main Collieries in Yorkshire, with a total capacity of 1,000 tons; a similar bunker for the Coppee Company at Coedelly, South Wales; a number of bunkers for the British Aluminium Works at Kinlochleven, including one of 80,000 cubic feet capacity and one of the largest suspended bunkers attempted in this country.

Water towers have been built to the firm's design at Topsham (capacity 50,000 gallons; height 80 ft.); and others of similar design and capacity at Rolleston and Ham Green, near Bristol. About fifteen years ago a reservoir with a capacity of 150,000 gallons was designed for the Bristol Electricity Department.

One of the earliest large elevated tar tanks, with a capacity of 100,000 gallons, was designed in 1911 for the Aldershot Gas Company; more recently two other elevated tar and liquor tanks, each with a capacity of 250,000 gallons, have been designed for the same Company. Other gas works structures include one of the first reinforced concrete purifying tanks, for the Northampton Gas Company, and a number of coke bunkers, coal bunkers, gantries, raft foundations, and similar structures. During the war the firm designed the whole of the reinforced concrete foundations, quay walls, elevated bunkers, etc., for the extension of the Leeds Corporation Electricity Works.

Marine works include Padstow Pier (800 ft. long by 40 ft. wide); a quay wall at Port Talbot; a wharf 1,000 ft. long carrying four railway lines and heavy cranes for the Port Talbot Dock and Railway Co.; a coaling pier at Woolwich Arsenal with a length of 1,000 ft. and wide enough to carry several railway lines, a large transporter, and other plant; a pier at Shellhaven for the Asiatic Petroleum Co.—this structure is built in the shape of a Tee, and stands in very deep water, the piles of the T head having 30 ft. without bracing.

Other buildings and structures for which the firm designed the reinforced concrete are the Royal Infirmary at Bristol; Leeds Infirmary extension; a warehouse 200 ft. long by 100 ft. wide with six floors and a flat roof, for Pilkington Bros., Ltd.; mills in Yorkshire for Messrs. T. F. Firth and Messrs. Patons & Baldwins; a grain silo with a height of over 120 ft. and a capacity of 13,000 tons of grain for the Co-operative Wholesale Society at Avonmouth; the new General Post Office at Singapore, now under construction and expected to cost about £1,000,000 when complete. Abroad are a Bank at Lagos; a bank at Demarara; Administrative Buildings at Para, Brazil; warehouses at Hankow, China; several buildings at Antwerp; and many others.

Illustrations of some of Messrs. Coignet's works are given elsewhere in this issue.

Concrete Manufacturers (No. 1 London), Ltd.

Commenced business some five years ago as manufacturers of pre-cast concrete units for housing purposes and general work. The firm manufactures extensively such articles of garden furniture as are portable, concrete kerbs of all standard sections, fencing posts, manholes, concrete pipes, concrete for the nursery, the farmer and the billposter. House and factory construction is also undertaken, and stocks are held of breeze slabs, and the general line of hoods, steps, sills, mullions, heads, etc.

Concrete Piling, Ltd.

Started business in 1912. Contracts recently carried out are as follows:—Foundations: Piling on the "Monolith" system for the North British Locomotive Co., Glasgow; Goole Shipbuilding Co.; Dundee Shipbuilding Co.; Barclay, Curle & Co., Glasgow; Hinde & Hardy, Norwich; Henry Ford & Sons, Cork; National Spelter Works, Avonmouth; and Pilkington's Glass Works, Doncaster. Pre-moulded Piling for cold store sheds at the Royal Albert Docks; new power station, Barking; sub-stations and train sheds for electrification scheme, Southern Railway; Gas Light & Coke Co. at their Bromley and Beckton Gas Works. Wharves have been constructed for the Southampton Corporation; Bell Bros., Middlesbrough; Queenstown Dry Dock & Shipbuilding Co. Coal bunkers for the Belfast Corporation and the Gas Light & Coke Co., as well as gas purifiers and a water tower for the latter body.

The firm carried out the complete construction of the new power station and further extensions for the Belfast Corporation, the covered reservoir at Bickley for the Metropolitan Water Board, and the reconstruction of the open-air baths at Windsor.

[*Concrete Piling, Ltd., Contractors.*

6,000-Ton Coal Bunker now under Construction at Beckton.

The Concrete Unit Co., Ltd.

Floated as a Limited Company in 1923, previous to which it had been in existence for some time. The firm specialises in the

[*Supplied by the Concrete Unit Co., Ltd.*

Concrete Fence Posts.

manufacture of pre-cast concrete units, and amongst the schemes to which reinforced concrete posts have been supplied may be mentioned the Anglesey roads contract, Rhyl-Gronant road, Whitehaven water supplies scheme, and housing schemes such as Manchester, Salford, Rochdale, Rotherham, Sheffield, etc. In addition to supplying all necessary materials for a concrete fence, the company has a staff of fixers who carry out contracts in any part of the country. The firm also undertakes reinforced concrete constructional work, including designing.

Considère Constructions, Ltd.

The Company was formed in 1908 to carry on the business of consultant designers for reinforced concrete structures.

Among the more important of the earlier works designed by the firm may be mentioned Wharves at Aberdeen Harbour, 3,300 ft. in length (1908), a Jetty at Gravesend, Bridge over the Mersey at Warrington, the widening of Dover Admiralty Pier, and the renewal of the West Wharf at Millbay Docks, Plymouth (1909); Grain Silos at Meadowside for the Clyde Navigation Trustees, Coaling Staithes at Derwenthaugh for the Consett Iron Co., Royal Insurance Buildings in Lombard Street, and a Furniture Depository for the Pall Mall Deposit Company in 1910; in 1911 there were carried out a Storage Reservoir for the Oldham Corporation, Art Galleries for the Glasgow Corporation, six Warehouses and two Conveyor Subways at Kingston-on-Hull for the Hull Joint Dock Committee, and a Jetty for the Admiralty at the Crombie (Fifeshire) Royal Naval Ordnance Depot.

[*Considère Constructions, Ltd., R. C. Designers.*

Warrington Bridge (134-ft. Span by 80 ft. Wide.)

In 1912 there were Offices at Millbank for the British-American Tobacco Co., Ltd., and new Tailors' Workshops at Cathcart; while in 1913 the firm designed the reinforced concrete for Malt Barns at Port Dundas for the Distillers Co., Ltd., a Pump-house at Dalmarnock for the Glasgow Corporation Electricity Department, caissons at Sunderland for the River Wear Commission, a Store at Scotstoun for the Anchor Line Steamship Company, a gantry for electric cranes at Greenwich for Wm. Cory & Sons, Ltd., a Pump-house building for the Devonport Electricity Department, a Pattern Store and Shop at Glasgow for the North British Diesel Engine Works, Offices on the Clyde for Stephen & Sons, Ltd., a Cathedral at Georgetown, Demarara, to the architectural design of Mr. Leonard Stokes, PP.R.I.B.A., and a Furniture Depository at Kensington for the Pall Mall Deposit Co.

Work carried out during the war included: 1914—Bottling Stores at Glasgow for McEwan & Co., Ltd.; Warehouse at Aberdeen for Alex. Pirrie & Sons, Ltd.; seven Jetties at Royal Albert Docks for the Port of London Authority; and a Crushing Plant House and Storage Platform at Corrales for the Tharsis Sulphur & Copper Co., Ltd. 1915—Power House at Tharsis for the Tharsis Sulphur & Copper Co., Ltd.; 4,000-ton limestone bunker at Dinmoor Park Quarry, Anglesey; a Bunker for the Wolverhampton Electricity Department; Coal Bunker and Cooling Plant at Tharsis for the Tharsis Sulphur & Copper Co., Ltd.; Crosslee Mills, Paisley, for R. & J. Jack & Co., Ltd.; Extensions to Wharf at Clarence Iron Works, Middlesbrough, for Bell Brothers, Ltd.; Wharf at Redcar for Dorman, Long & Co., Ltd. 1916—Silos at Cambus for the Distillers Co., Ltd., and a Boiler House for the Wolverhampton

Electricity Department. 1917—Wharves at Belfast for Harland & Wolff, Ltd.; Boiler House for the Sheffield Electricity Department; Aviation Shop, 700 ft. long, at Belfast for Harland & Wolff, Ltd.; and a Joiners' Shop at Liverpool for the same firm. 1918—Wharf Wall at Brentford Dock for the Great Western Railway Co.; Sub-station at Dalmarnock for the Glasgow Electricity Department; reconstruction of Adelphi Distillery for the Distillers Co., Ltd.; and a Bridge over East Ham Manor Way for the Gas Light & Coke Co.

In the years immediately following the war there were: 1919—Dennistoun Sub-station for the Glasgow Corporation Electricity Department; Maltings at Bristol for the Distillers Co., Ltd.; Sub-station at Holmfauldhead for the Glasgow Corporation Electricity Department; Bonded Warehouse at Port Dundas for the Distillers Co., Ltd.; Purifiers at Beckton for the Gas Light & Coke Co.; Workshops for the Clan Line Steamers Co., Ltd.; Coal Hoppers at Bromley for the Gas Light & Coke Co.; Store Building at Dalmarnock; and a Sub-station in Cadogan Street for the Glasgow Corporation Electricity Department; Hudson's Depository, Wilton Road, S.W.1; and a Depository at Barnes.

In 1920 the works designed included a Suspended Drain at Greenhithe for the Empire Paper Mills, Ltd.; Spinning Mills at Flint for Courtaulds, Ltd.; and the reconstruction of the East Quay, Newhaven, for the London, Brighton & South Coast Railway. 1921—Buchanan Street Sub-station and No. 2 Water Intake at Dalmarnock for the Glasgow Corporation Electricity Department; and a Deep-water Wharf for the London & Thames Haven Oil Wharves, Ltd. 1922—Bridges over the River Cart at Pollokshaws and Monkland Canal for the Glasgow Corporation; Ore Storage Bins at Corrales for the Tharsis Sulphur & Copper Co., Ltd.; and a Sulphate House for Bell Brothers (By-Products), Ltd. 1923—Baths and Wash-houses at Pollokshaws and Dalmarnock Power Station for the Glasgow Corporation Electricity Works; St. Regulus Club, St. Andrews; Bonded Stores at Markinch for John Haig & Co., Ltd.; the Russell Institute; and a Bridge over the river Roding for the Ilford U.D.C.

Among more recent works may be mentioned: Waterside Bridge, Aberdeenshire; Baths and Wash-houses at Whiteinch and Oswald Street Bridge for the Glasgow Corporation; Crown Site, Kensington, for John Barker & Co., Ltd.; River Don Bridge, Inverurie; Liverpool, London & Globe Insurance Co.'s premises, Charing Cross; three Bridges on the Renfrew Road Diversion for the Clyde Navigation Trustees; Bridge at Gilfach for the Gellygaer U.D.C.; Bonded Store at Cameronbridge for the Distillers Co., Ltd.; Pandy Bridge for the Monmouthshire C.C.; Swimming Bath at Croydon; Factory at Wapping for D. & W. Gibbs, Ltd.; Dalmarnock Power Station Extensions for the Glasgow Corporation Electricity Department; 6,000-ton Coal Bunker for the Gas Light & Coke Co.; Coke and Breeze Bunkers for the Aberdeen Gas Department, Works at Witham, Essex, for the British Oxygen Co.; Baths at Hillsborough for the Sheffield Corporation; Scarborough Harbour; Pump-house, Coal Store, etc., for the Wolverhampton Electricity Department; Bridge over Lea Navigation for the Middlesex C.C.; Felton Bridge for the Northumberland C.C.; Maryhill Road Bridge, Glasgow, for the Glasgow Corporation; Piling at Chelsea Creek for the Great Western Railway.

Other illustrations are given in connection with an article elsewhere in this issue.

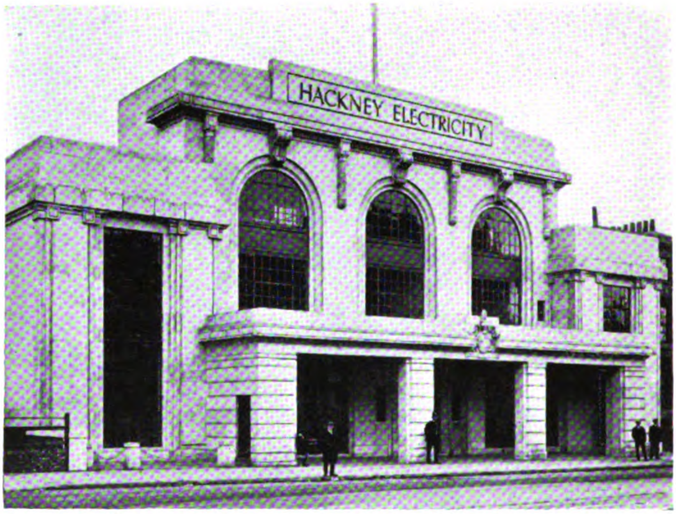
Croft Granite, Brick and Concrete Co., Ltd.

Came into existence in 1868; formed into a Limited Company in 1898. The firm's products are more or less indicated by its title and include paving flags, kerb and channel, posts, artificial stone-work, garden ornaments, and almost anything which can be produced in concrete or reconstructed stone.

Empire Stone Company, Ltd.

Commenced business in 1900. Contracts carried out in reinforced concrete include: Floors to Rawson & Sons' factory, Leicester, in 1908 (one of the first large factories in England in which the floors were entirely of reinforced concrete); Floors to J. Rowley & Sons' factory, Leicester (reconstruction after fire); Transit shed, Wapping, for Royal Mail Steam Packet Co., in which the main decking beams span 51 ft.; 17 miles of reinforced concrete seating to the Stadium at the White City; Retaining wall, Piccadilly, London, for the Royal Insurance Co.; Several swimming baths in different parts of the country; Reinforced concrete raft at Adderley Park, Birmingham, for the Wolseley Motor Co., Ltd., to carry a three-story building; Floors to new works and offices of the Dunlop Rubber Co., Ltd., Birmingham; Complete Building in reinforced concrete for the Royal Mail Steam Packet Co., Ltd., at Kingston, Jamaica, to replace buildings destroyed by earthquake; and reinforced concrete carcase, consisting of framed columns, barrel vaults and dome, of St. John's Church, Rochdale.

Contracts where "Empire" stone has been used include: London and North Western Railway—sub-stations (Euston to Watford widening in connection with electri-



[*Cast-Stone by Empire Stone Co., Ltd.*

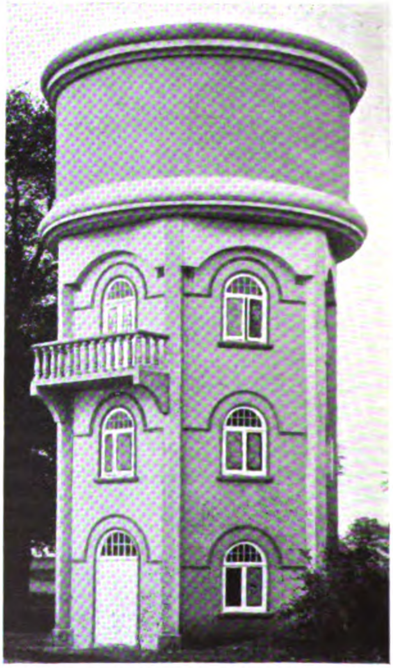
Showroom for Hackney Electricity Undertaking.

fication of line) (1913); Duchy of Cornwall Estate, block of flats, Kennington (1911); Ovaltine factory, Kings Langley, and extensions (1922); Peter Robinson's new premises, Oxford Circus (main cornice and all staircases) (1923–24); Hackney Sub-station, DalstonLane, for Hackney Electricity Undertaking (further contract in hand for new showrooms and offices in Lower Clapton Road) (1924); Extension of Conservative Club, Little St. James's Street, S.W. (1924); Messrs.Bradleys' Extensions, Hereford Street, Bayswater (1924); Balustrading round Indian War Memorial Gardens, Brighton (1923); Secondary schools, Ditchling Road, Brighton (1925); Entrance staircase and balustrading to Guildhall, Winchester (1914); Power station, Stourport (1923); Lotus Shoe factory, Stafford (1922); Central Picture House, Sheffield (1922); Offices for the Staveley Coal and Iron Co., Ltd., Staveley (1923–24); St. John's Church, Rochdale (1923–24); Victoria Hospital, Worksop (1924); Central premises for Mansfield & Sutton Co-operative Society, Ltd., Mansfield (1919); Delta Metal Works, Birmingham (1910); Secondary school, King's Norton (1908); Mitchell & Butler's Capehill Brewery, Birmingham; Premises for Messrs. Morris Engines, Ltd., Coventry (1924); Premises for Triumph Cycle Co., Ltd., Coventry (1923).

Evans Bros. (Concrete), Ltd.

Established 21 years ago as a building firm, and gradually developed more and more into reinforced concrete construction. Since the war the development has been more on the lines of pre-cast concrete and cast stone and a short time ago the firm was divided into two portions, one Messrs. Evans Bros. & Co., builders and contractors, an entirely new firm under separate ownership, the other Evans Bros. (Concrete), Ltd., who specialise in cast stone-work and pre-cast concrete and undertake only a limited amount of reinforced concrete construction. The firm also acts as consulting engineers for reinforced concrete design, supplies steel, and by arrangement bends and fixes same into position ready for the general contractor.

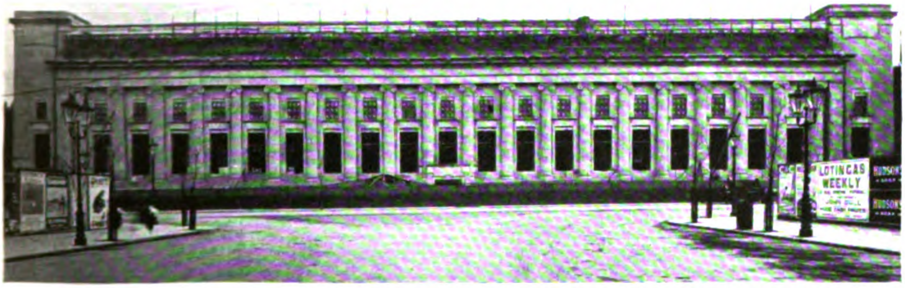
Work carried out includes a dome, 45 ft. diameter and 30 ft. high, together with flat



[*Evans Bros. (Concrete), Ltd., Contractors.*

Water Tower at Rolleston.

roofs (*see p.* 18); Mills for the Derbyshire Education Committee; Retaining wall at Staveley for the Derbyshire County Council; North-light roof building at Sutton-in-Ashfield; Casing in up-cast colliery head-stocks on steel framework whilst winding was being carried on; Covered reservoir tank at Haddon Hall; Water tower (45,000 galls., 40 ft. above ground at Rolleston); Covered water reservoir, 65 ft. by 65 ft. by 11 ft., at Codnor Park; Covered water tower at Higham; Elevated water tank at Newton, for the Blackwell Rural District Council; Elevated tanks at Pye Bridge, for the Midland Acid Co., Ltd.; Bridge at Chesterfield; Culvert at Spittall, Chesterfield; Water-softening tanks at Bromboro Port, for Messrs. Lever Bros.; Water-softening tanks at Bentley Colliery; Complete concrete building, three stories, for Co-operative Society at Kirby-in-Ashfield; Flat roof, 45 ft. clear span, over winding engine house whilst winding engines were continually at work; Machine shop floors for Vickers, Ltd., at Sheffield; Elevated telpher house for Sheffield Gas Works; Elevated bunkers, etc., for tar macadam at Ambergate; Elevated bunkers for washed coal at Orgreave Colliery.



[*Reinforcement by Expanded Metal Co., Ltd.*

British Museum Extension.

Expanded Metal Co., Ltd.

Expanded Metal, introduced over thirty years ago, was used in its earlier days for partitions, ceiling work, etc., as well as for fencing, guards, and in various forms of pre-cast goods. Following upon tests made in 1896, the material was introduced to engineers as a reinforcement for concrete, and since that date it has been used in considerable quantities for this purpose.

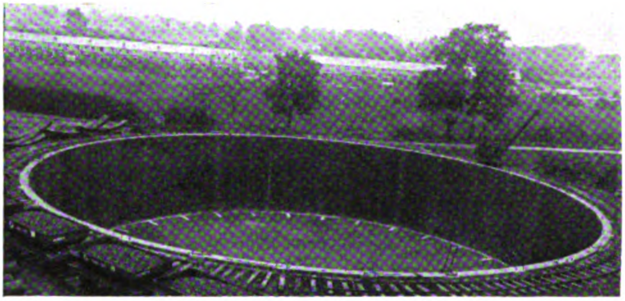
Amongst the more important buildings in which these reinforcements have been used may be mentioned the following: British Museum Extension; Technical Institute, Newport, Mon.; Pavilion at Torquay; Lacon's Brewery, Great Yarmouth; University Press, Oxford; Lots Road Generating Station of the Underground Railways Company; Marischal College, Aberdeen; University College, Dublin; Cerebos Salt Factory, Co. Durham; Leicester and Rutland Counties Asylum, Narboro'; Bracebridge Asylum, Lincoln; Girls' County School, Cambridge; Tuberculosis Sanatorium, Cottingham Hall; Acton Cottage Hospital Extensions; King Edward VII. Sanatorium, Ipswich; British Bank of South America, London; Westminster Bank, Leicester; Hibernian Bank, Dublin; Swimming Baths at South Shields, Halstead, Brimscall, Woolwich, Salford, Wisbech, etc.; Cement Silos; Coke Hoppers; Water Towers at Dublin, Downpatrick, Hartlepool, Holsworthy, etc.; G.W.R. Goods Warehouse at Brentford; Reservoirs at Watford, Camborne, Hursley Park, Exeter, Ambergate, Leeds, Leatherhead, Loch Leven, Birmingham, etc.

The racecourses at Gosforth Park, Ascot, and York are built with the use of the firm's reinforcements, as also are the Football Stands at Middlesbrough, Dublin, and elsewhere. Other buildings include Picture Theatres, Garages and Workshops, Colliery Structures, Houses, Churches, Public Buildings, etc., in various parts of the world. Sir John J. Burnet & Partners were the architects for the extension of the British Museum, illustrated herewith.

F.C. Construction Co., Ltd.

Formed in 1922 with the object of executing the design and construction of all classes of reinforced concrete structures. Up to the present the firm's efforts have been mainly in industrial structures and foundations.

Some of the more important works include:



[*F.C. Construction Co., Ltd., R. C. Designers and Contractors.*

Gasholder Tank, 162 ft. Diameter by 33 ft. Deep, at Swindon.

Foundations and structures in connection with the carbonising and the coal and coke handling plant at Swansea Gas Works, constructed on piles in marshy ground; Piled gasholder foundations at Troon and Aberystwyth, and a number of ordinary slab foundations throughout the country; Carbonising plant foundations at Congleton, Gravesend, Manchester, Morecambe, Goole (piled), etc.; Purifier houses at Tunbridge Wells and Goole, and purifier foundations at Paisley, Romford, Blackburn, Aldershot, etc.; Coke and coal bunkers at Southport, Newcastle-on-Tyne, Lytham, Chesterfield, Rockingham, etc.; Washery bunkers and sub-structure, together with conical settling tank, at Cwm; Gasholder tank, to hold about 4,250,000 gallons of water, for the Great Western Railway Co., at Swindon; Retaining walls at Newcastle-under-Lyme, Plymouth, etc.; Tar, liquor or water tanks at Chesterfield, Durham, and Newcastle-under-Lyme.

Work at present in hand includes a bunker in Yorkshire to hold 4,000 tons of iron ore.

Fram Reinforced Concrete Co., Ltd.

Commenced business 1900. Among contracts carried out are reinforced concrete and floor construction at Messrs. Whiteley's Stores, London; the Liverpool Cotton Exchange; Lloyds Bank, Manchester; Refuge Assurance Buildings, Manchester.

Other works executed in reinforced concrete include: coal bunkers, railway sidings, etc., at Bradford Road Gas Works, Manchester; and retaining walls, bunkers, and railway sidings, at Partington, for the Manchester Corporation.

Gloucester Concrete Construction Co., Ltd.

Formed in 1917 as "The Gloucester Ferro-Concrete Ship Building Co., Ltd.," and built six 1,000-ton ferro-concrete barges for the Director-General of Merchant Shipbuilding. On the completion of this programme it was decided to continue the Company for the manufacture of pre-cast concrete products, and a change of name was made.

The present output of the Company, whilst it includes breeze and concrete blocks, as well as posts, paving, etc., largely consists of architectural dressings. A number of stock lines are made, but the bulk of the work is to architects' designs. These dressings are made closely resembling natural stone, and are made in various colours. Sills, doorhoods, steps, etc., have been provided for various housing schemes, and dressings and steps have been supplied to the Great Western Railway Company at various points as well as to the Co-operative Wholesale Society for new premises in several towns.

The following brief list of some of the firm's contracts illustrate the different types of work carried out: Staircases and coping for the Royal Berkshire Nurses' Home at Read-

[*Fram Reinforced Concrete Co., Ltd., R. C. Designers and Contractors.*

Railway Sidings at Bradford Road Gasworks, for the Manchester Corporation.

ing; dressings for the "George and Dragon" Hotel at Abingdon and the "New" Inn at Berry Hill, Coleford; particularly large cast stones for the Dilke Memorial Hospital near Cinderford, and the Lydbrook Memorial Hall, Forest of Dean. An example of the Company's work may be seen at Cheltenham, in the dressings for a large new boarding house for the Ladies' College, for which Messrs L. W. Barnard, F.R.I.B.A., and Partners, are the architects. Balustrading and similar work is to be found in numerous private houses, as well as at Barry, Glam., where it is being used in the extensions to the public gardens, etc.

[Cast-Stone by Gloucester Concrete Construction Co., Ltd.

St. Margaret's Boarding House, Ladies' College, Cheltenham.

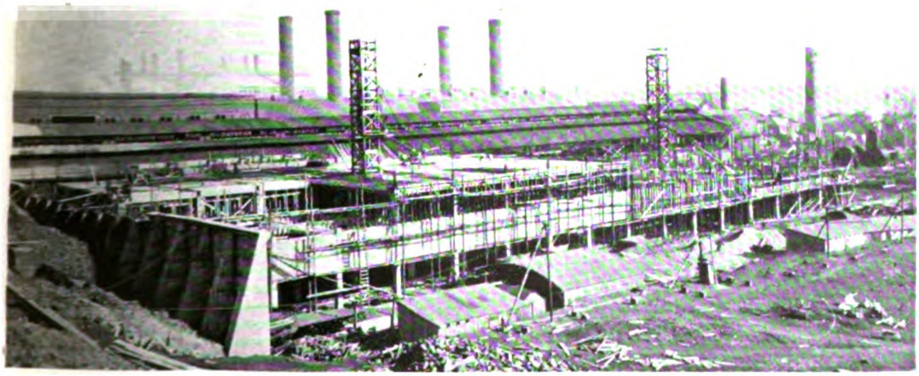
Gray's Ferro-Concrete Co., Ltd.

Commenced business in 1911. Recent contracts carried out include:

1922: Purifiers, coke hoppers, gantries, etc., for the Glasgow Corporation Gas Department; Filters and tanks at Kilmarnock for the Paterson Engineering Co., Ltd.; Warehouse at Blackfriars, London; Reservoir at Nuneaton; Mission hall, Glasgow (floors, etc.); Cadoro restaurant, Glasgow.

1923: County Hospital, Motherwell; Montague Hospital, Mexborough; Loco shed at Ashington; Culvert at Stevenston for the Ayrshire County Council; Reservoir at Whitehaven for the U.D.C.; Reinforced concrete road near Lugton, for the Ayrshire County Council; Whaley Bridge, for the Derbyshire County Council; Diversion of Renfrew Road for the Clyde Navigation Trustees (three ferro-concrete bridges); Reservoir at Longhill for the Stirlingshire and Falkirk Water Board; Filter units, precipitation tanks, chemical house, etc., for the South Staffordshire Waterworks Co.; Mission hall at Wimbledon; Grain silos for the Board of Agriculture; Trent Bridge widening, Burton-on-Trent.

1924: Salvage works, Tyseley, for the Corporation of Birmingham; Service reservoir, for the Burgh of Castle Douglas; Vaulting and roof, Episcopal Church, Rosyth; Rolfe Bridge, for the County Borough of Smethwick; Victoria Infirmary, Glasgow (floors, etc.); Silos at Birkenhead; Bunkers and crusher foundations at Cove Quarry, near Aberdeen; Bunkers at Dawsholm Gas Works, Glasgow, for the Glasgow Corporation Gas Department.



[Gray's Ferro-Concrete Co., Ltd., Contractors.

Catch-Boxes and Purifier-Boxes at Provan Gasworks, Glasgow.

1925: Bridge over Leeds and Liverpool Canal, Whitebirk, for the County Borough of Blackburn; Bathing station, etc., for Largs Town Council; Filter units, precipitation tanks, sludge tanks, etc., also general buildings, at Talybont-on-Usk, South Wales, for the Paterson Engineering Co., Ltd.; Drip bridge over river Forth for Counties of Stirling and Perth; Harwood Loop bridge, for the County Borough of Blackburn; Delabole Reservoir, for North Cornwall Joint Water Board; three bridges for the Fylde Water Board; Bow Bridge, Bannockburn; Filter units and machinery house at Ponststigill, South Wales, for the Paterson Engineering Co., Ltd.; Several bridges and road schemes in Ayrshire for the Northern District Council of Ayrshire.

[Gray's Ferro-Concrete Co., Ltd., R. C. Designers and Contractors.

Banquetting Hall at the Cadoro Restaurant, Glasgow.

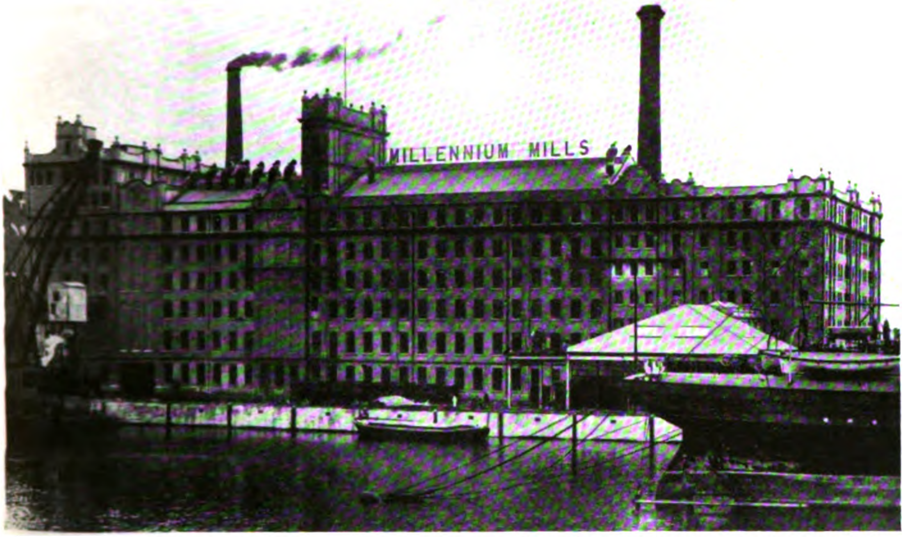
Holland & Hannen and Cubitts, Ltd.

The firm of Cubitts was established in the year 1815, and the founder of the firm, Thomas Cubitt, may indeed be regarded as the creator of residential London—Highbury, Pimlico, Belgravia and Clapham were planned and built by him. It may be of interest to quote an extract from the *Observer* of November 6, 1825, which was reprinted by the same paper on November 8, 1925: "The rage for building in the vicinity of the Metropolis continues unabated. The extensive track of ground between Millbank and Chelsea, which has long supplied the London market with some of their best and earliest vegetables, has lately been let on a building lease by Earl Grosvenor to Mr. Cubitt, the builder of Gray's Inn-lane, who has delivered in a plan of 5,000 houses to be there erected. The market gardeners, by whom they are at present occupied, have received notice to quit."

Thomas Cubitt was later joined by his brother William, and it may be claimed that they were the pioneers of the building trade as it is to-day.

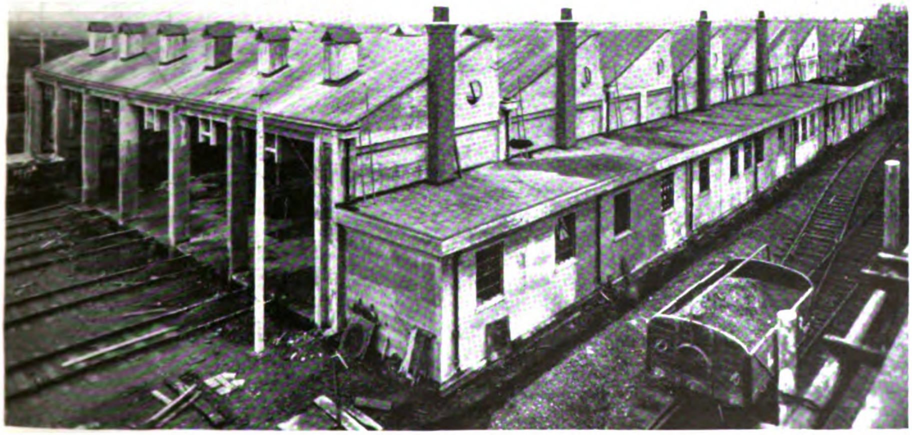
In 1882 the two firms of William Cubitt & Co. and Holland & Hannen formed an alliance, and in 1909 the combined firms were incorporated as a limited liability company under its present title of Holland & Hannen and Cubitts, Ltd. To its credit stand such buildings as Euston Station, Coutts' Bank, Glyn, Mills, Currie & Co.'s Bank, Prudential Assurance Co.'s offices, Grocers' Hall, Fishmongers' Hall, and the centre of London government—the new County Hall. Among West End houses may be mentioned Waring & Gillows, Woollands, a portion of Harrods, and other establishments of a similar nature. At the moment the firm is erecting a large block of shops and flats on the Devonshire House site in Piccadilly as well as Messrs. Cooks' new offices in Berkeley Street.

The success of the business is largely attributable to its ready investigation of new ideas and methods. The Company were perhaps the chief supporters of ferro-concrete



[Holland & Hannen and Cubitts, Ltd., Contractors.

Millennium Mills, Victoria Docks, London.



[Mr. A. W. Szlumper, C.B.E., M.Inst.C.E., Engineer; Holloway Bros. (London), Ltd., Contractors.

Engine Shed and Gravitation Yard at Feltham for the Southern Railway.

on its introduction to this country, and have carried out many large works in this material, including the mammoth flour mill for Messrs. Vernons at Victoria Docks, a drill hall at Chatham, Messrs. Roder's factory at Willesden, Messrs. Hudson & Kearns' printing works, and various other contracts of a similar nature. A large number of concrete piles have been driven at sundry riverside premises, and the total area of ferro-concrete floors executed by the Company under different systems must be prodigious.

Holloway Bros. (London), Ltd.

The two brothers, Thomas and Henry Holloway, started business in the year 1882 at Victoria Works, Queen's Road, Battersea; eighteen years later they removed to larger premises in Belvedere Road, Westminster, part of the site on which the new County Hall stands. Their present chief executive offices and wharf are at Grosvenor Road, Westminster, the stonemasonry works are at Battersea, and the joinery department at Earlsfield. The engineering branch, with offices also at Newcastle-on-Tyne, has developed largely during recent years, and the firm have carried out important undertakings in the construction of sea-defence works, docks, shipyards, bridges and roads.

[K. Holst & Co., R. C. Designers and Contractors.

Reinforced Concrete Bridge at King's Lynn.

Among the works carried out in reinforced concrete are a wharf and jetty at Dorman Long & Co.'s works at Redcar; fitting-out basin and dry dock at Tees Shipyard for Messrs. Wm. Gray & Co., Ltd.; new locomotive depot for the Southern Railway at Feltham; Reading Bridge (the largest single-span ferro-concrete bridge in the country); bridge over the Darenth at Farningham, Kent; Esk Bridge, Carlisle; improvement of London Docks, consisting of widening and deepening the passage to the Tobacco Dock, construction of Impounding Station, concrete dam, and ferro-concrete jetty in West Dock; Caversham Bridge, Reading; Berwick Bridge, etc. The gravitation yard at Feltham was designed by Mr. A. W. Szlumper, M.Inst.C.E., Chief Dock Engineer, Southern Railway.

K. Holst & Co.

Commenced operations as engineers and contractors specialising in ferro-concrete work in 1918, and have since that date designed and erected a large number of ferro-concrete structures of all types for public authorities and industrial concerns.

Bridges have been carried out for several County Councils and Corporations, the most important being the Freebridge of 500-ft. span over the river Ouse at King's Lynn, which was completed last summer at a cost of nearly £30,000.

Reservoirs, water towers and other water-containing structures form a large proportion of the work executed by the firm, and among these may be mentioned a gas-holder tank, 172 ft. in diameter and 35 ft. deep, for the Dundee Corporation, and elevated tanks at Weston-super-Mare and Woodville.

Buildings of the factory and warehouse type have also been erected for a number of industrial firms, the most noteworthy being a factory at Hull for Messrs. Herbert Green & Co., Ltd., and various colliery structures for the Powell Duffryn Steam Coal Co., Ltd., and other collieries in South Wales and elsewhere. For gas works the firm has constructed a number of bunkers, tar and liquor tanks, etc., and have now in hand a set of purifiers at Nine Elms for the Gas Light & Coke Co., costing over £20,000.

Hughes & Lancaster, Ltd.

Established in 1865. The firm manufactures the "Bonna" reinforced steel and concrete pipe—the invention of M. Aimé Bonna. This pipe has been extensively used on the Continent since 1894, and the firm acquired the sole rights for its manufacture in this country and the Dominions and Colonies in 1914.

[*Hughes & Lancaster, Ltd., Contractors.*

Pipe Manufacturing Depot on the Thirlmere Aqueduct.

Our illustration shows the "Bonna" pipe manufacturing depot at Longridge, immediately adjacent to the line of the Thirlmere Aqueduct in connection with the 4½ miles of 54-in. internal diameter main which the firm constructed for the Manchester Corporation's Fourth Thirlmere Pipe Line.

In addition to this large contract, the firm has carried out work for the Leeds Corporation (42 in. diameter), Birmingham Corporation (60 in. diameter), Tilbury Urban District Council (42 in. diameter for surface water outfall), and Cardiff Corporation (24 and 36 in. diameter.)

Hull Concrete Stone Co., Ltd.

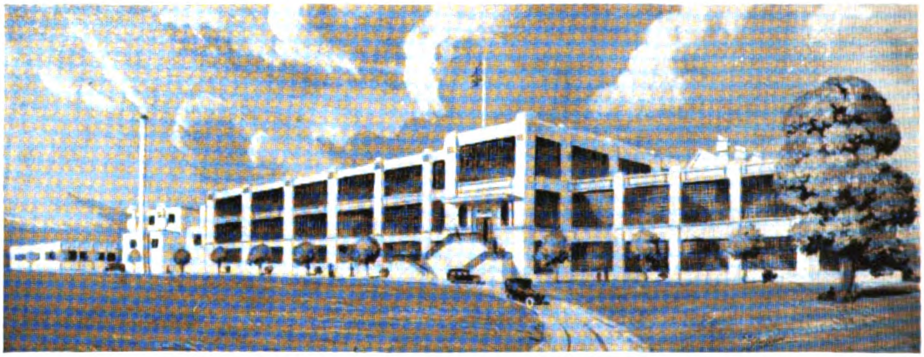
Incorporated in 1920, continuing the business of an older Company, which went out of existence in Hull the previous year. The following are some of the architectural works carried out during the past five years: Front elevation, all tracery windows, and all internal arches, etc., at the Park Presbyterian Church, Middlesbrough; Hall at Middlesbrough; "Savoy" Theatre, Hull; "Cecil" Theatre, Hull; "Grand" Theatre, Gainsborough; Tracery window at St. Augustine's Church, Hull; Balustrading to bridge at East Park Lake, Hull; Garage, board room, and saw-mills' front for Messrs. Reckitt & Sons, Ltd., at Hull; Café at Peasholm, and lavatories and shelters for the Scarborough Corporation.

F. D. Huntington, Ltd.

Commenced business early in 1919. Amongst the more important contracts executed are the following:—Extensions to Messrs. Selfridge's premises, Oxford Street, W.; factory for Bryant & May, Ltd., Garston; store premises, Oxford Circus, for Grands Magasins du Louvre; head offices over St. James's Park Station for Metropolitan District Railway; flats, Mansfield Street, W.; premises in Golden Square and Warwick Street, W., for Dormeuil Frères; office building, 188–190 Fleet Street, E.C., for Gresham Insurance Co.; store premises for Fuller's, Ltd., Regent Street, W.; warehouse for Boots Pure Drug Co., Stamford Street, S.E.; store premises for Boots Pure Drug Co., Lincoln; distributing depot for the British Petroleum Co., Ellesmere Port; housing scheme for Synthetic Ammonia and Nitrates, Ltd., Billingham; R.A.F. Stations for the Air Ministry at North Weald (Essex) and Tangmere (Sussex); reinforced concrete factory for Shredded Wheat Co., Welwyn Garden City; distributing depots, service

[*Cast-Stone by Hull Concrete Stone Co., Ltd.*

Cast-Stone Facing to Park Presbyterian Church, Middlesbrough.



[Louis de Soissons & Arthur W. Kenyon, FF.R.I.B.A., Architects; F. D. Huntington, Ltd., Contractors.

Factory for the Shredded Wheat Co., Ltd., at Welwyn Garden City.

stations, garages, etc., in many parts of the country for Anglo-American Oil Co., Ltd.; sub-stations for the Metropolitan Railway at Harrow and Rickmansworth; office building for Benn Brothers, Ltd., Fleet Street, E.C.; stores premises for Upsons, Ltd., St. Paul's Churchyard, E.C.

Indented Bar & Concrete Engineering Co., Ltd.

Formed in 1906 under the name of "The Patent Indented Steel Bar Company, Ltd.," the title being altered to its present form in 1911. Since that date a large number of structures of various types have been carried out in accordance with designs prepared by the Company. These include Abbassia Barracks, Cairo; 2,000,000-gall. reservoir, Runcorn; cold store and transit shed for Port of London Authority; warehouses for Ralli Bros., Ltd., Manchester, J. Sainsbury, Ltd., London, Pullars, Ltd., Perth, etc.; 400,000-gall. water tower, Cleethorpes; 250,000-gall. water tower, Broadstairs; factories for Lever Bros., Ltd., at Bromborough, and Castner Kellner Alkali Co., Ltd., Runcorn, etc.; bathing pool, Cleethorpes; sea wall, Ramsgate; calcining plant, Irthlingborough; power station for United Alkali Co., Ltd., Widnes; coal bunkers at Islington, Glasshoughton, etc.; stadium, White City; Pirelli's Works, Southampton; grain silos, Liverpool; Capitol Cinema, Cardiff; ore gantry, Middlesbrough; gas works, Portslade.

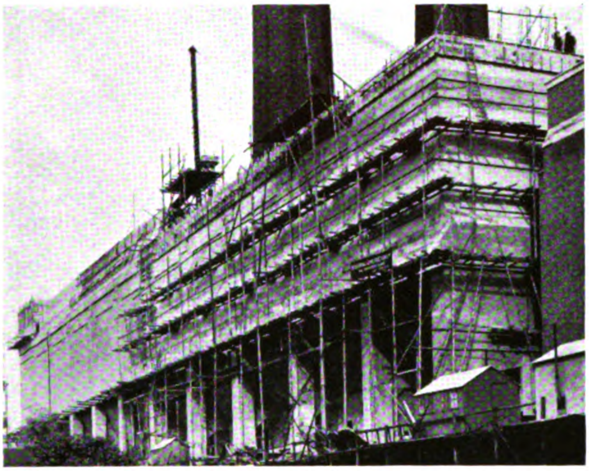
Amongst the works with which the Company are at present dealing the following are some of the more important:—Two large bridges and many smaller ones; several large warehouses; 750,000-gall. water tower, over 150 ft. high; 4,500,000-gall. cooling pond; an important sea wall; a large bathing pool and foreshore development scheme; municipal offices; nearly 50 schools for various county councils (including 25 for the Middlesex County Council); school and offices on the Gold Coast, Africa.

In addition to the above works, which have been designed by the Company in London, branches in Aus-

[Indented Bar & Concrete Engineering Co., Ltd., R. C. Designers.

Cartway for the Port of London Authority: Beams 50-ft. span.

tralia, New Zealand, and South Africa have dealt with a large number of structures such as bridges, power stations, water towers, etc. The Company also controls the " Hollocast " concrete floor.



[Industrial Constructions, Ltd., R. C. Designers and Contractors.

10,000-ton Coal Bunker for the London County Council, now in course of Construction.

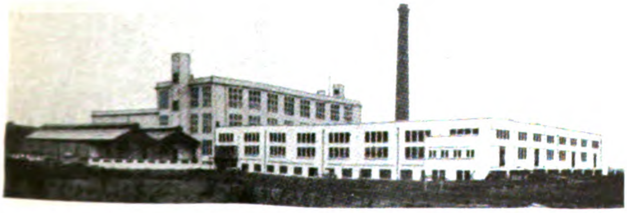
Industrial Constructions, Ltd.

Commenced business 1920. Contracts carried out include filtration plant at Beckton ; gas purifiers at Wolverhampton ; offices at Consett ; filtration plant at Melton Mowbray ; compressor house at Gelli ; sand bins at Charlton ; pithead air lock at Askern ; gas purifiers at Croydon ; 2000-ton coal storage ; bunker and circular tar tanks at Consett washery building at Taffs Well ; coke bunkers at Sheffield ; 3,000-ton drainage-bunkers at New Monckton ; washery building at Abertridwr ; washery building at Bargoed ; power station at Watford ; washery building at Mickley ; bunker at Hardwick ; filtration plant at Ossett ; 2,000-ton coal storage bunker and 3,000-ton coal storage bunker at Redbourn ; 10,000-ton coal storage bunker at Greenwich ; water tower at Slough ; cooler foundations at Consett ; reservoir at Taff Merthyr ; reservoir at Kenilworth ; water tower at Cromer ; coke bench and ram bench at Redbourn ; and reservoir at Bungay.

A. Jackaman & Son, Ltd.

Established 1899. Among the most important works carried out by the firm are : Warehouse and quay widenings at London Dock and West India Docks (Import and Export), and a wharf and warehouse for the meat trade traffic at Royal Victoria Dock, for the Port of London Authority ; jetty and transport shed at Parkeston Quay, continental pier at Harwich (reconstruction), and dock wall at Lowestoft, for the Great Eastern Railway Co. ; warehouses at Brentford Dock, wharf at Port Talbot, and coal tip and traverser tracks at Cardiff, for the Great Western Railway Co. ; wharf in river Usk, Newport, Mon., for the Alexandria Dock and Railway Co. ; cold stores, Cardiff, for the Cardiff Railway Co. ; Ryde pierhead reconstruction, dolphins to floating dock, at Southampton, and engine sheds at Exmouth Junction, for the Southern Railway Co. ; wharf at Ipswich Dock, for the Ipswich Dock Commissioners ; wharf and water tower and warehouse floors at Silvertown, for Venesta, Ltd. ; corn silos at Ipswich for R. & W. Paul, Ltd. ; corn silos at Bermondsey for Spillers & Bakers, Ltd. ; corn silos at Silvertown for the Co-operative Wholesale Society ; quay and fish market at Grimsby for the Great Central Railway Co. ; bridges at various places for the Middlesex County Council.

Illustrations of some of Messrs. Jackaman's contracts are given elsewhere in this issue.



[Mr. F. E. L. Harris, Architect ; Reinforcement by Johnson's Reinforced Concrete Engineering Co., Ltd.

Co-operative Wholesale Society Factory at Irlam, Manchester.

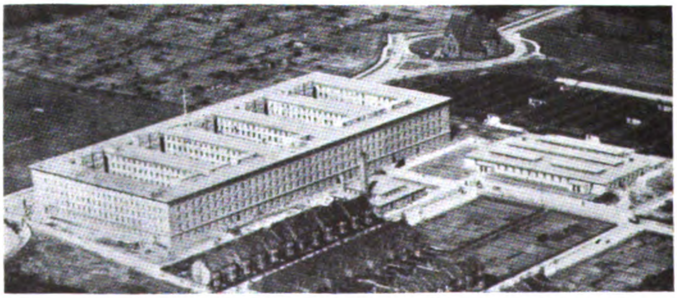
Johnson's Reinforced Concrete Engineering Co., Ltd.

Johnson's steel wire lattice was first used for reinforcing the floors in the Savoy Hotel, London, in 1903, and this is about the date of the commencement of this business as a department of Messrs. Rd. Johnson, Clapham & Morris, Ltd. From that date it went on to develop, introducing the "Keedon" system some few years afterwards, coupled with wire lattice reinforcement, until the department became an independent company, under its present title, in 1919.

Some of the principal contracts which might be referred to are as follows:—Manchester Ship Canal Transit Sheds, offices, and other buildings, spread over several years' work; factories and warehouse at Nottingham for the Imperial Tobacco Co.; several buildings for the Lancashire and Yorkshire Railway Co.; tanks and buildings for the Midland Railway Co.; soap factory for the Co-operative Wholesale Society, Ltd., Irlam; warehouses for the Liverpool Warehousing Co., Ltd.; warehouses for Hay's Wharf, Ltd., London; jetties and piers on the Thames for Hay's Wharf, Ltd.; retaining wall, wharf wall, and jetty for the British Petroleum Co., Ltd.; wharf wall, jetty and buildings on the Thames for Bowaters Paper Mills, Ltd., Northfleet; colliery headgears, heapsteads, and other buildings for the Wigan Coal & Iron Co., Ltd., Arley Colliery Co., Ltd., Baddesley Collieries, Ltd., Ansley Hall Coal & Iron Co., Ltd., Sutton Manor Collieries, Ltd., Ibstock Collieries, Ltd., Collins Green Colliery Co., Ltd.

Walter Jones & Sons, Ltd.

Founded 1890. Contracts carried out in reinforced concrete include; Offices to accommodate 7,000 clerks for the Ministry of Pensions (£250,000); Reinforced concrete foundations at Mount Pleasant Post Office, for H.M. Office of Works (£50,947); Foundations, power station, railway sidings, etc., for the Mersey Power Co. (£47,951); Reinforced concrete gas purifiers, bunkers, tanks, etc., for the Gas Light & Coke Co. at Beckton (£50,000); Reinforced concrete structures for the Morgan Crucible Co., Ltd. (£50,000); Reinforced concrete coal bunkers for the Northampton Gas Co. Reinforced concrete water softeners and filtering tanks for the Croydon Electric Co.; Reinforced concrete office building in Woodstock Street, W. (£10,000); Reinforced concrete bridge carrying the Chertsey Arterial Road over the London & South Western Railway (£9,000); Reinforced concrete factory at Ratcliff (£20,000); and Reinforced concrete bridge over Barking Creek and Viaduct for the Ministry of Transport (£76,363).



[Walter Jones & Sons, Ltd., Contractors.

Pensions Offices, Acton.

Kirk & Randall, Ltd.

Established in 1874. During the period since the war, the company has been engaged in constructional works which include the erection of 320 houses for the Romford Rural District Council, of which number one-half were concrete; reinforced concrete quay east of the Ouseburn, for the Newcastle-upon-Tyne Corporation; reinforced concrete quay and foundations for transit sheds at Trafford Wharf for the Manchester Ship Canal Co.; river wharf wall of concrete blocks on the Thames, for the Chiswick U.D.C.; reconstruction in ferro-concrete of the East Pier at Shoreham Harbour; extension of the sea wall and esplanade at Hove, with flint-faced concrete blocks; extension to Lonsdale Dock, Workington, with new entrance thereto and other works (in progress); a dock and other works at Bromborough, Cheshire, for Messrs. Lever Brothers, Ltd. (in progress).

[Kirk & Randall, Ltd., R. C. Designers & Contractors.

Quays at Workington.

In addition, contracts for large building works and housing schemes have been completed or are in process of execution.

John Laing & Son, Ltd.

Established in 1874. Amongst the more important contracts carried out are: Reconstruction of Catterick Camp for H.M. War Office; Aspatria, Silloth & District Water Works; Barrow-in-Furness Outfall Sewer Works; Cumberland & Westmorland Mental Hospital; New Science Buildings at Bangor University; Pumping Station at Littleton for the Metropolitan Water Board; Aerodromes at Wittering, Spittlegate, Catterick, Crail, Cramlington, etc., for H.M. Air Ministry; St. Nicholas Bridges, Carlisle; and Grandstand at Lingfield Race Course for the Jockey Club.

Among their other constructional activities Messrs. Laing are at present engaged on the erection of concrete *in situ* houses on their "Easiform" system, which gives a complete cavity to all external walls.

[John Laing & Son, Ltd., Contractors.

Concrete Cottages at Carlisle.

Peter Lind & Co.

Established as designers and contractors on September 1, 1915. Among the more important contracts carried out are: Gas purifiers and gasholder foundations at Crewe, for London, Midland & Scottish Railway; pile foundations and substructure for new mill at Purfleet, for Thames Board Mills, Ltd.; pile foundations, tanks, etc., at Morriston Gas Works, South Wales; headgear and winding engine house at Denaby Main Colliery; pit lining and winding engine house at Pontypridd; bunker, granary, and fan casing at Llanbradach; arch bridge over the River Aire for the Bradford Corporation; stove and meter works at Fulham for the Gas Light & Coke Co.; 2,000-ton coal bunker at Fulham Gas Works; purifiers at Bargoed; bunkers at Risca and Pontypridd; stables at South Lambeth; foundations for turbo-alternators at Newport, Croydon, Bilsthorpe, Purfleet, and Kensington; service reservoirs at Wolverhampton and Folkestone; grain silos at Erith; bridge over the river Stow for the Norfolk County Council; warehouse at Bermondsey; a number of road bridges and culverts for the Middlesex County Council; workshops, purifiers, and coke hoppers at Beckton for the Gas Light & Coke Co.; machine shops at Smethwick for the Birmingham Railway Carriage and Wagon Co. Ltd.; plumbers' shop at Wallsend, for Swan, Hunter, and Wigham Richardson, Ltd.; bunkers at Colchester, Southampton, Coventry, Greenwich, Newcastle and Nine Elms; power station at Bargoed, for the Powell Duffryn Steam Coal Co., Ltd.; power house at Consett, for the

[Peter Lind & Co., R. C. Designers and Contractors.

Stove and Meter Works at Fulham for the Gas Light & Coke Co.

[*Peter Lind & Co., R. C. Designers and Contractors.*

Footbridge for the Bradford Corporation.

Consett Iron Co., Ltd.; power station at Bilston, for Alfred Hickman, Ltd.; 4 bridges for the Metropolitan District Railway; and elevated water tanks at Scunthorpe, Jarrow, and Morriston.

Liverpool Artificial Stone Co., Ltd.

Formerly known as "Breeze Slabs (Liverpool), Ltd.," the firm was established six years ago and its present weekly output exceeds 3,000 cubic feet of architectural dressings, 2,000 yards super of granolithic paving slabs and kerbs, 1,500 yards super of breeze partition slabs, and a quantity of modelled garden ornaments. The architectural work is composed of granite chippings moulded to detail and finished by hand 1 in. deep on all exposed faces to match the texture and colour of any natural stone. The paving slabs and kerbs are made in hydraulic presses, and are submitted to 600 tons pressure. The breeze partition slabs are composed of well-burnt brown ashes, crushed $\frac{3}{16}$ in., to dust, treated for chemical impurities and submitted to 250 lbs. per sq. in. pressure.

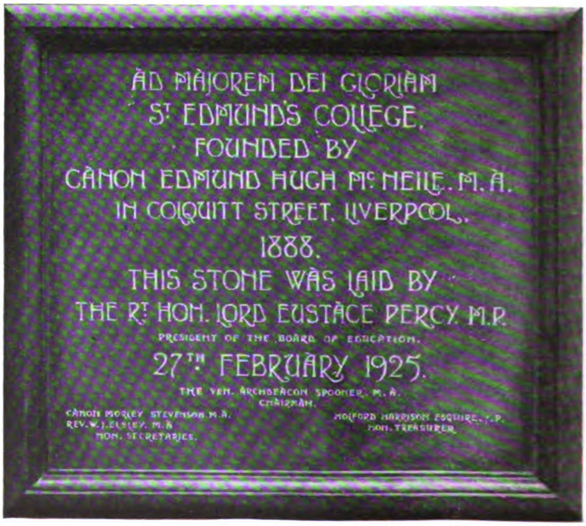
The foundation stone illustrated was executed to match Runcorn stone, and was sufficiently dense to permit the inscription to be cut into the stone and letters gilt filled, all the arrises being perfectly sharp and clean. The average tensile strength of the firm's material is 520 lbs. per sq. in., and compression strength 7,300 lbs. per sq. in. at 7 days.

Sir Robert McAlpine & Sons.

Although the firm has carried out many very large contracts, it will undoubtedly be chiefly thought of in connection with the Empire Exhibition, the largest building enterprise the world has ever known, and creating another record in also having within its borders the largest stadium in the world. The huge palaces of Engineering and Industry each comprise over 20 acres of floor space, and are probably the largest roofed-in spaces in the world. The Stadium, costing over half a million pounds, was built within the short space of twelve months, in spite of labour troubles. The architects for the Exhibition, practically the whole of which is in reinforced concrete, were Messrs. Simpson & Ayrton, FF.R.I.B.A., and the engineer was Sir Owen Williams, K.B.E., M.Inst.C.E.

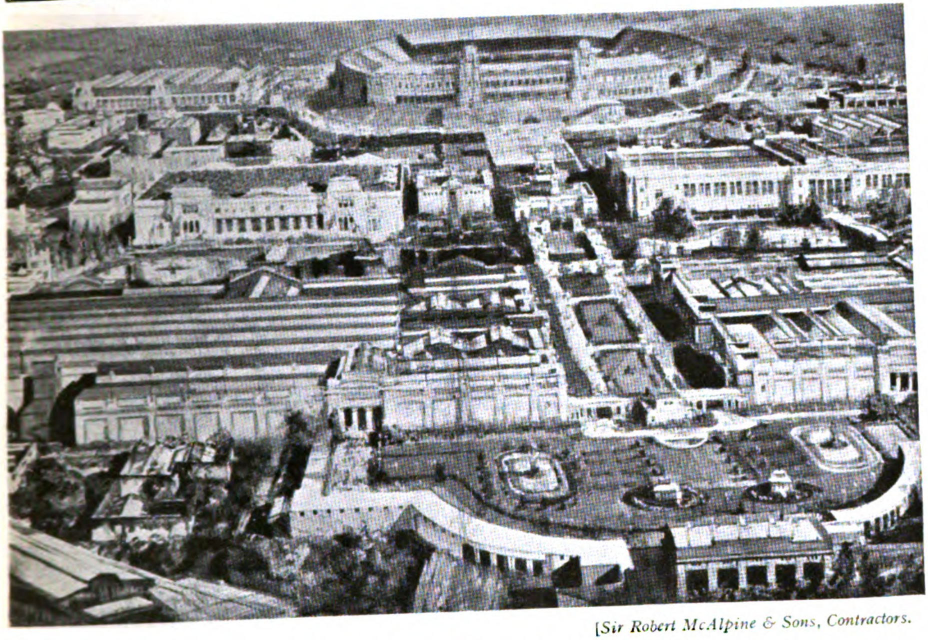
F. A. Macdonald & Partners.

The founder of the firm first became connected with reinforced concrete construction in 1902. Since that date many works have been carried out to its designs, among which may be mentioned :—Foundations and


AD MAJOREM DEI GLORIAM
S^T EDMUND'S COLLEGE,
FOUNDED BY
CANON EDMUND HUGH M^C NEILE. M. A.
IN COLQUITT STREET, LIVERPOOL.
1888.
THIS STONE WAS LAID BY
THE R^T HON. LORD EUSTACE PERCY. M.P.
PRESIDENT OF THE BOARD OF EDUCATION.
27^TH FEBRUARY 1925.
THE VEN. ARCHDEACON SPOONER, M. A.
CHAIRMAN.
CANON MORLEY STEVENSON M.A.
REV. W. J. ELSLEY. M.A
HON. SECRETARIES.
HOLFORD HARRISON ESQUIRE, J.P.
HON. TREASURER.

[*Made by Liverpool Artificial Stone Co., Ltd.*

Foundation Stone to match Runcorn Stone: Lettering Incised and Gilt-filled.



[*Sir Robert McAlpine & Sons, Contractors.*

British Empire Exhibition, Wembley.

cantilever galleries and roofs at the Usher Hall, Edinburgh; dam across the river Ettrick at Philiphaugh; pier on the island of Raasay; pier and railway bridge at Almeria, Spain; foundations for vertical retorts at Arbroath, Alloa, and Motherwell Gas Works; tanks and coke hopper at Alloa Gas Works; domed roofs at Rankeilour House, Kirkcaldy; power house, bunkers and wharfs for the Newcastle General Electric Supply Co.; factory buildings and stores at Kirkcaldy, Paisley, Kilbagie, Rutherglen, Caldercruix, Edinburgh, Glasgow, and elsewhere; eight football stands in Lancashire and Yorkshire; water tanks at Kirkcaldy and Prestonpans.

Other works of different types bring the total to over five hundred.

Among the works at present under construction are: Dam across the river Ettrick at Selkirk; tank for the London & North-Eastern Railway at Cowlairs; floors and roofs at Bonnyton Brickworks, Kilmarnock; floors at Edinburgh; tank at Alloa Gas Works; retaining wall at Paisley; roofs for the Fife Linoleum Co.,

[*F. A. Macdonald & Partners, R. C. Designers.*

House at Kirkcaldy, with Concrete Domed Roofs.

[*F. A. Macdonald & Partners, R. C. Designers and Contractors.*

Wire Rope Works at Rutherglen.

Kirkcaldy; floors and roofs at Galashiels Burgh Buildings; St. John's Church, Perth; Paisley Abbey; and the Scottish National War Memorial, as engineers to the contractors, Messrs. Stuart's Granolithic Co., Ltd.; warehouse at Dunfermline; floors at St. John's R.C. School, Portobello; floors at Edinburgh, for Messrs. Stuart's Granolithic Co., Ltd.; and several other works of a similar nature.

Monnoyer British Construction Co., Ltd.

Incorporated in 1922, the firm is an offshoot of Leon Monnoyer et Fils, of Brussels. Established in 1874 as engineers and contractors, Leon Monnoyer et Fils have to their credit many important works carried out in Belgium, and were among the pioneers of reinforced concrete work. Their first work in reinforced concrete goes back as far as the year 1901, when they erected a bridge over the river Senne at Brussels.

Up to date the firm has carried out some 150 important contracts in reinforced concrete in Belgium, England, France, Spain, and Russia. The Palace Hotel in Brussels (400 rooms) was completed in 40 weeks in 1909, while the Palace Hotel in Madrid (2,000 rooms) was completed in 16 months in 1911.

The firm took out several patents, among them perhaps the best known being the "Claveaux Monnoyer" used to build chimney shafts in reinforced concrete. Hundreds of these chimneys are to be seen on the Continent. This patent was also applied to the erection of water towers, a good example of which is shown in the illustration.

Since its establishment in England the firm has carried out works of various description, such as a large building in Regent Street, and, in the reinforced concrete sphere, a sea wall at Ramsgate 3,000 ft. long, a reservoir for the Melton Mowbray Urban District Council, and are at present extending the pier at Herne Bay for the Urban District Council.

Mouchel & Partners, Ltd.

The late Louis Gustave Mouchel, after resigning his position on the staff of the *Ponts et Chaussées*, under which he had been engaged chiefly in marine and harbour engineering works, settled in 1875 at Briton Ferry, where he was appointed French Consul and afterwards promoted to the rank of *Conseiller du Commerce Exterieur*.

About 1895 he employed "Hennebique" ferro-concrete in the erection of industrial buildings and house property in Briton Ferry and elsewhere in South Wales, and the success of these operations decided him to undertake the introduction of ferro-concrete into this country and to make this the main object of his professional life.

Having overcome initial prejudice to what was then regarded as a new method of doubtful character, M. Mouchel removed his headquarters to Westminster, where he established

[*Monnoyer British Construction Co., Ltd., R.C. Designers and Contractors*

Reinforced Concrete Water Tower.

a technical organisation, with district offices under the charge of qualified engineers in different parts of the country. In this way he was able to cope with the rapidly-increasing demands for designs and to exercise thorough supervision over the execution of contracts, which were entrusted only to authorised contractors of adequate experience. In course of time, the practice was converted into a limited company under the style of L. G. Mouchel & Partners, Ltd., of which Mr. T. J. Gueritte is the Managing Director.

Some of the pioneer structures of different classes in Mouchel–Hennebique ferro-concrete are : Weaver's Flour Mills and Granaries, Swansea (1897) ; river wall, river Itchen, Southampton (1897) ; oil mills at Liverpool (1898) ; Great Western Railway warehouse, Brentford (1899) ; Woolston jetty, Southampton (1899) ; engineering workshops, Liverpool (1899) ; Meyrick Park water tower, Bournemouth (1900) ; Brunswick dock sheds, Liverpool (1900) ; quayside warehouse, Newcastle-on-Tyne (1900) ; Chewton highway bridge (1901) ; Medical College extension, London Hospital (1901) ; office building, Mersey Docks and Harbour Board (1902) ; Copnor Schools, Portsmouth (1903) ; cement clinker bins, Haverton Hill (1903) ; coal bunkers, G.W.R., Park Royal (1904) ; Drill Hall, Chatham (1904) ; motor garage, Kirkburton, Yorks (1905) ; King's Theatre, Sunderland (1906) ; Roedean swimming bath, Brighton (1906) ; Eastney sewage tanks (7-million gals.), Portsmouth (1906) ; Liverpool football grandstand (1907).

The first highway bridge was the Chewton Bridge (1900). The first canal bridge (1903) was for the Liverpool Corporation, and had a 50-ft. span. The first bowstring girder bridge was at Purfleet, 60-ft. span (1903). The first bridge in Scotland (and the first railway bridge in the Kingdom) was the Dundee Harbour Road and Railway Bridge (40-ft. span). The first viaduct in Ireland was the riverside viaduct at Waterford (1905). The first river covering was section 1 of River Roch enclosure, Rochdale (1904). The first bridge widening was Milford Bridge, Derby (1906). The first tramway bridge was at Smethwick in 1906 (span 42 ft.). The first bridge in Wales was Glanyafonddu Bridge, Carmarthen (1908). Th first railway over-bridge was at Virginia Water Station (1907). The first mainline railway bridges were Avonmouth and Filton Railway (1907) and Victoria Street Bridges, Great Western Railway (1908). The first highway bridge in Ireland was Drumlone Bridge (1908). The first tramway bridge in London was the New North Road Bridge (1912). The first London County Council bridge was St. John's Hill Bridge Clapham Junction (1915). The first Thames bridge was Reading Bridge (arch span 180 ft.), built in 1923.

[L. G. Mouchel & Partners, Ltd., R. C. Designers.

Reinforced Concrete Bridge at Reading.

Some of the largest Mouchel-Hennebique girder bridges are : Waterford Riverside Viaduct (1905), 720 ft. ; Waterford River Bridge (1910), 720 ft. ; Lougher (1921), 720 ft. ; Eggington Bridge and Viaducts (1925), 723 ft. ; Dover Viaducts (1913), 1,000 ft. ; Trent Bridge widening, Burton (1925), 1,180 ft.

The largest span arch bridges are : Esk Border Bridge (1915), 175 ft. ; Reading Bridge (1922), 180 ft. ; Berwick Border Bridge (under construction), 361 ft.

Some brief details of a few of the more interesting reinforced concrete buildings designed by the firm, with the date of erection, are as follows : Weaver's Flour Mills and Granary, 130 ft. maximum height. Quayside Warehouse, Newcastle-on-Tyne (1900) : 7-story building on raft on deep mud—additional story built on roof 1909. Dunston Works of Wholesale Co-Operative Society, Ltd. (1901) : grain-cleaning house, 155 ft. by 110 ft. by 94 ft. high with 56 grain silos with 35,000 qrs. storage capacity ; circular grain silos (1907) : soap and glycerine factory (1907) : Six silos each 72 ft. high by 45 ft.

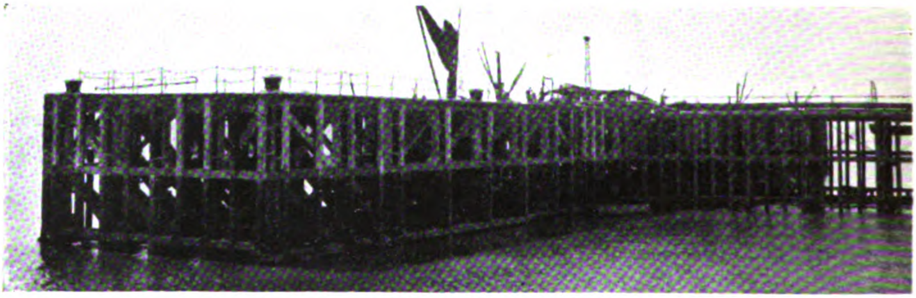
diameter, with 60,000 qrs. storage capacity; adjoining other structures, the whole making a range of riverside buildings fronted by ferro-concrete wharfs and jetties. N.E.R. goods station and warehouse, Newcastle-on-Tyne (1903): 430 ft. by 178 ft. by 63 ft. high; high-level station on first floor for main-line rolling stock. Dock sheds, Manchester (1903): 2,250 ft. long by 112 ft. wide—three stories high. Millennium Mills, Victoria Docks (1904): 350 ft. by 140 ft. by 120 ft. high. Drill hall and barracks, Chatham (1904): all of ferro-concrete, including roof principals, framing and covering. G.P.O. extension, London (1907); public office, 201 ft. by 60 ft. by 85 ft.—sorting office, 312 ft. by 185 ft. by 63 ft.—area 15 acres of floors, 8,000,000 cu. ft. contents. Royal Liver building, Liverpool (1908): First British "skyscraper," 361 ft. high, 300 ft. by 175 ft. area, 17 stories. Granary at Bermondsey (1908): First building exempted by L.C.C. from 1894 Building Act. Port of London Dock Sheds (1910 and 1912): West London Dock: 1,260 ft. by 64 ft.; 763 ft. by 160 ft.; 763 ft. by 160 ft. E.I. Import Dock: 420 ft. by 50 ft. W.I. Import Dock: 720 ft. by 65 ft.; 720 ft. by 65 ft.; 826 ft. by 65 ft. H.M. Stationery Office (1911): 480 ft. by 220 ft. by 77 ft., average height.

Jetties, wharves, quays, docks, reservoirs up to 7,000,000-gallons capacity, water towers up to 3,000,000-gallons capacity, coal bunkers up to 4,000-tons capacity, cement bunkers, stone bunkers, foundations, and other works have been designed and built in reinforced concrete in various parts of the country.

John Mowlem & Co., Ltd.

This is one of the oldest London contracting firms, having been founded at South Wharf, Paddington, in 1820, by John Mowlem, who subsequently took into partnership Joseph Freeman and George Burt, D.L., J.P., of Swanage. On the death of these partners the business was carried on by their sons—John Mowlem Burt, George Burt, and William Robert Freeman—the first of whom received a knighthood in connection with the work carried out by the Company in Westminster Abbey for the Coronation of King Edward VII. The business was converted into a private limited liability company in 1903, and into a public company in June, 1925, the present Directors being Mr. Edwin John Burt, son of Sir John Mowlem Burt; Mr. George Mowlem Burt and Mr. Eric Burt, both sons of Mr. George Burt; Mr. E. B. Beck, and Mr. James Marsden.

The Company held a Royal Warrant as builders to Edward Prince of Wales, which was renewed on his accession to the throne as King Edward VII, and they also hold a similar Royal Warrant as builders to H.M. King George V.



[*John Mowlem & Co., Ltd., Contractors.*

Jetty at Shellhaven.

The activities of the Company are very widely spread, and in fact embrace every kind of building, contracting, engineering, and road and sewer work, the small list below giving some indication of the importance and diversity of the work they have executed. Among important buildings in London may be mentioned Billingsgate Fish Market; the Imperial Institute at South Kensington; the Institution of Civil Engineers and the Institution of Mechanical Engineers, both in Great George Street; H.M. Office of Woods and Forests in Whitehall; the work in connection with the Queen Victoria Memorial, including the Processional Road, the Admiralty Block IV, and Arch at the end of it; Regent Palace Hotel; Liverpool Street Station; Victoria Station (L.B. & S. Coast Railway); widening of Grosvenor Road Railway Bridge over the river Thames; widening of the line to Croydon; Port of London Authority Head Office in Trinity Square, which has the largest reinforced concrete dome in this country; Bush House, Aldwych; and the foundations

[John Mowlem & Co., Ltd., Contractors.

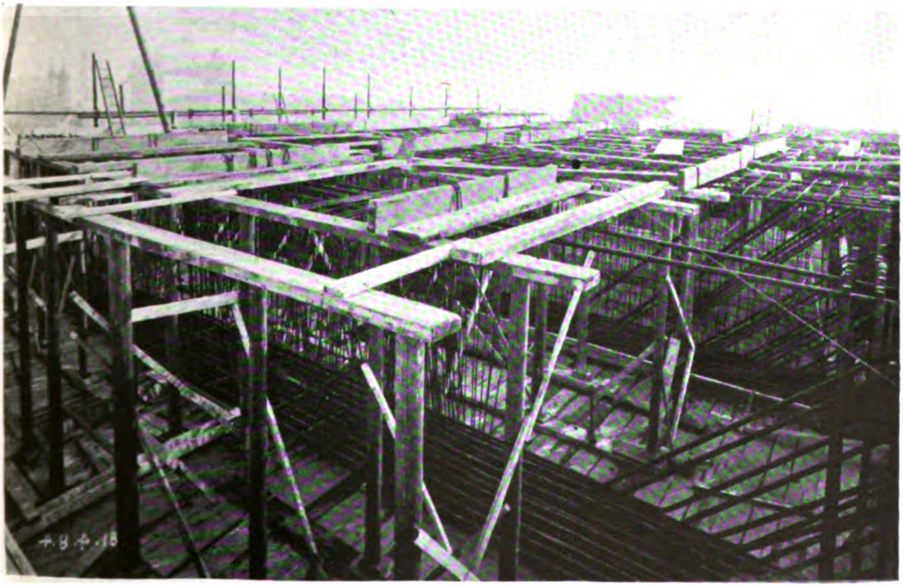
Corner of River Wall, Wandsworth.

for Lloyd's new building in Leadenhall Street. They also executed a large proportion of the Underground Railways of London, including the line from Euston to Camden Town; the Post Office London Parcels Tube Railway from Paddington to Whitechapel; the Embankment wall from the Houses of Parliament to Lambeth Bridge; and several miles of tramway routes for the London County Council, including some very intricate bridge work crossing main-line railways. Outside London are the Dover Patrol Memorial (on the Dover side); Minterne House, Dorset; housing schemes at Woolwich and for the Government in connection with Woolwich Arsenal employees; and housing schemes for the Furness Shipbuilding Co., at Haverton Hill, Middlesbrough.

During the war the Company carried out extensive Government works, including the construction of munition factories at Coventry, Hereford, and Ellesmere Port; reinstatement of the devastated area caused by the Silvertown explosion; aerodromes at Harling Road (Norfolk) and several in the Salisbury Plain district.

They also erected a large part of the building fronting Oxford Street, Great Portland Street, and Great Castle Street, for Peter Robinson, Ltd.; the new Star and Garter Home for Disabled Soldiers and Sailors at Richmond for the British Red Cross Society; new premises for the Banque Belge in Bishopsgate; "K" Tobacco Warehouse, for the Port of London Authority; Montague Arms, Beaulieu; and College of Nursing, Cavendish Square.

In reinforced concrete, the Company has constructed a large jetty and installation for

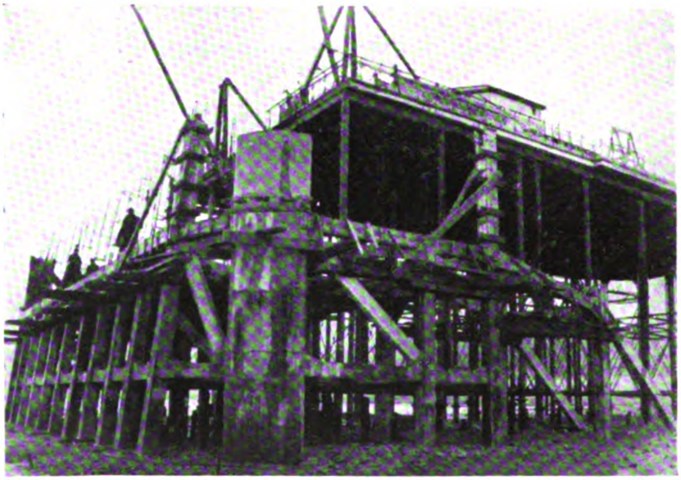


[Sir Edwin Cooper, F.R.I.B.A., Architect; John Mowlem & Co., Ltd., Contractors.

Construction of the Base of the Dome of the new P.L.A. Building.

the Shell-Mex Co. at Shellhaven, Essex, and similar work for the British Petroleum Co. at Wandsworth. Other ferro-concrete works are: the "Z" Mill for the Morgan Crucible Co. at Battersea; Portsmouth Reservoirs (Contracts Nos. 1 and 2); Sheffield Reservoirs; Maidstone Waterworks; and Grosvenor Road Pumping Station for the London Hydraulic Power Co.

For about thirty-five years the Company has held almost continuously the contract for H.M. Office of Works for the repairs and maintenance of the whole of the Government buildings in the London district, including the Royal palaces, museums, public offices, etc. They are also contractors for the Port of London Authority for the maintenance and repair of the whole of the docks of the Port of London. They have carried out many important main-laying contracts for the Metropolitan Water Board, and also held a contract for the repair and maintenance of a large section of the Board's mains for the supply of London. Since the abolition of the London County Council's Works Department they have also held a contract under which all the maintenance work of the sewers and bridges under the Council's control is executed by them.



[*Nott, Brodie & Co., Ltd., Contractors.*

Penarth Pierhead, now in course of Construction.

Messrs. Mowlem are one of the largest of the quarry owners in the Island of Guernsey, where they produce macadam and setts for road work.

Nott, Brodie & Co., Ltd.

The firm is the successor of the late L. P. Nott, who commenced contracting in 1895 after the death of his father-in-law, Thos. A. Walker, contractor for the Severn Tunnel, Buenos Aires Docks, Manchester Ship Canal, and other large works.

In 1907 the firm constructed a 19-ft. span culvert on the B.R.C. system for Messrs. Lever Brothers at Port Sunlight; they have also constructed a number of other works in ferro-concrete, including the Cromarty Pier on the Considère system, and are now constructing the Penarth pierhead on the Hennebique system.

Other works include dock, reservoir, railway, bridge and road contracts all over the country of a total value of over three million pounds. Those running from £50,000 to £500,000 are as follows: — Peterhead Harbour Improvements; Prince of Wales Dry Dock, Swansea; North Dock entrance, Swansea; South Dock entrance, Swansea; New Dock, Llanelly; Lliedi Reservoir, Llanelly; Canada Branch Dock, Liverpool; Princes Risboro' Railway; Tranmere Docks; Wick Harbour improvements; Middle Dry Dock, South Shields; Llwynon Reservoir, Cardiff; Cromarty and Dingwall Railway; Clover's Graving Docks, Birkenhead; Bailey's Dry Dock, Newport, Mon.; Blaen-y-cwm Reservoir, Beaufort: and the construction of the Portway, at Bristol.

Perry & Co. (Overseas), Ltd.

Commenced business in 1837, and the principal works carried out, or now being carried out in ferro-concrete, are Tilbury Jetty, for the Port of London Authority; H.M. Stationery Office, Stamford Street, London; Glasgow Head Post Office extension; New General Post Office, Singapore; the Sailors' Institute, Singapore. The new Singapore General Post Office, which we illustrate, is the design of Major P. H. Keys, D.S.O., F.R.I.B.A., and is on the "Coignet" system; the cost of the work is estimated at £500,000.

Precast Concrete, Ltd.

Established 1919, as roofing contractors, and carried out many contracts in the North

[*Perry & Co. (Overseas), Ltd., Contractors.*

New General Post Office, Singapore (Coignet System), now under Construction.

of England and Scotland using their patent "Hollocon" roofing and "Hollocast" floors.

Recent flooring contracts executed or in course of construction: Reservoir cover for Bridlington Corporation (3,100 yds. of "Hollocast" beams fixed on pre-cast columns and reinforced concrete beams); Barnsley British Co-operative Society new premises, Barnsley (2,600 yds.); Huddersfield Building Society re-construction scheme, flooring, terrazzo work, marble walling, and cork flooring; Irwell Springs Printing Co., Ltd., Bacup (2,000 yds.); Deansgate Hotel, Manchester, extensions (1,200 yds.); C. & J. Hirst & Sons, Ltd., Huddersfield (1,500 yds.).

Reinforced Concrete Construction Co.

Commenced business as a firm in 1920, on the return of the present partners (Capt. F. Scholefield and Capt. G. W. Crawshaw) from active service. Capt. Crawshaw was the inventor and patentee, in 1911, of the "Crawshaw" pile helmet, which at the time made a big advance in the handling and driving of concrete piles. Since 1920 the contracts carried out by the firm include bridges for the Cheshire County Council (4), Cumberland County Council, Warwickshire County Council (2), Hereford County Council, Derbyshire County Council, Borough of Rochdale, and many Rural District Councils; railway bridge and jetty work for the Manchester Ship Canal Co.; retaining wall for the Borough of Preston. Amongst the contracts now in hand are four road bridges and a 800-ft. retaining wall for the Carnarvonshire County Council; reconstruction of Chirk Bridge for the Shrop-

[*Precast Concrete, Ltd., Contractors.*

Roof (3,100 yds. super) of Reservoir at Bridlington.

[*Reinforced Concrete Construction Co., Contractors.*

Little Hereford Bridge: Largest One-Span Concrete Bridge in West of England.

shire County Council; main road bridges for the Borough of Barnsley, the Royal Borough of Sutton Coldfield, and other reinforced concrete constructions for public authorities and private owners.

Saxild & Partners.

Commenced business in 1922. The firm specialises in the design and erection of dock, harbour works and marine works, such as wharves, jetties, quay walls, coast protection work, river walls, groynes, etc., and has carried out work of this nature in various parts of the country. The principal works completed in the London district comprise reinforced concrete wharves and quay walls on the Thames and Medway, all on the sheet-piling system; a quay wall at Fulham for the Gas Light & Coke Company is an example of a design for a heavy quay wall on this system, and a wharf built for Messrs. Fenning & Co., near Putney Bridge, with heavy crane gantries overhanging the river, is another example of this type. A wharf at Rochester for the Rochester Gas Works is also designed and built on the same lines.

In South Wales the firm is carrying out a number of reinforced concrete jetties for new heavy coal hoists in the Great Western Railway dock system. One jetty is completed at Newport, and two are under construction at Port Talbot. Other work in that part of the country includes extensions to the gas works at Teignmouth, including river-wall and retort bench foundations, coal stores, etc.

An example of the firm's contracts in the North of England is a cliff protection wall and promenade extension for the Whitley and Monkseaton Urban District Council at Whitley Bay. The firm's field of action extends as far as Orkney Island, where they have designed and erected for the Stromness Harbour Commissioners extensive works remodelling the whole harbour. The work comprised the new North Pier, entirely built in reinforced concrete as an open-pile structure, and also a wharf in front of Messrs. Thornley Binders' works.

In addition to the work mentioned above, the firm has important contracts running for work in their particular line in various parts of the country.

Walter Scott & Middleton, Ltd.

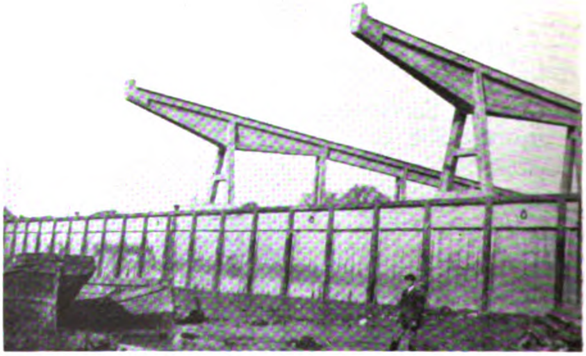
Founded in 1850 by Sir Walter Scott, Bt. (then Mr. Walter Scott).

Amongst other important reinforced concrete works carried out by the firm are several heavy bridges on the Great Western line, mainly in South Wales, and a bridge built for the Nottingham County Council at Muskham, entirely of reinforced concrete.

Simon-Carves, Ltd.

The firm opened a department for the design and construction of reinforced concrete structures a little over twelve years ago.

Among the leading contracts carried out are: For the South Kirkby, Featherstone & Hemsworth Collieries, Ltd., South Kirkby Colliery: 1,400-ton capacity storage bunker, 630-ton capacity washery bunkers, and 206,000-gall. capacity slurry tower; For Barber, Walker & Co., Ltd., Harworth Colliery: 300-ton capacity storage bunker, 780-ton capacity washery bunkers, 270,000-gall. capacity slurry tower, and pit-head air-locks and tub grantries to the screens; For



[*Saxild & Partners, R.C. Designers and Contractors.*

Quay Wall and Crane Gantries at Fulham.

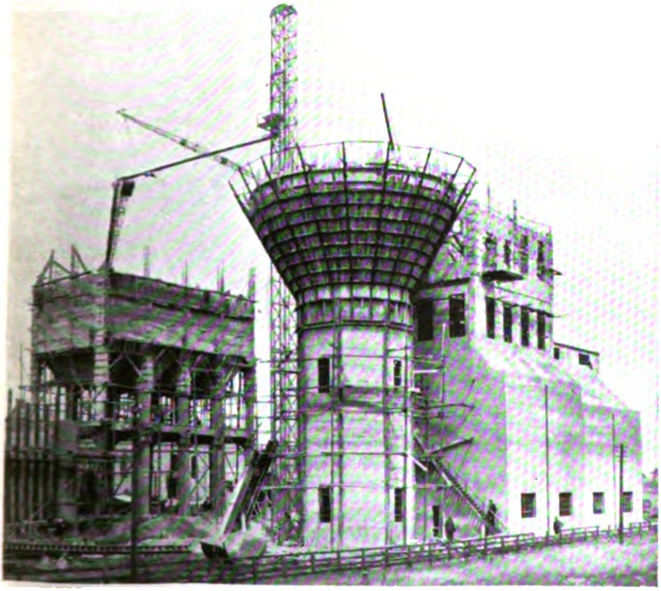
Guest, Keen & Nettlefolds, Ltd., Dowlais Colliery: Circular drainage bunkers, 3,000 tons total capacity, divided into 12 separate circular compartments with conical bottoms for drainage service bunker of 2,500-tons capacity, including bridge for carrying charging car to the ovens; For Stella Gill Coke & Bye-Products Co., Ltd.: 1,000-ton capacity storage bunker (including bridge for charging car to coke ovens), washery building and fine coal storage bunkers (1,200-ton capacity), slurry tank of 110,000-gall. capacity, water and tar tower combined, and underground feed hopper; For The Dalton Main Collieries, Ltd., Silverwood Colliery: Service bunker of 650-tons capacity designed to span over the ram engine track, so that the ram can pass completely under the bunker; For Great Western Colliery Co., Ltd., Pontypridd: Service bunker of 600-tons capacity (including reinforced concrete bridge to coke ovens) designed to take the pull of the aerial ropeway feed.

[*Walter Scott & Middleton, Ltd., Contractors.*

Muskham Bridge.

D. G. Somerville & Co., Ltd.

Founded in 1905. The principal contracts carried out by the firm and its associated companies include: Mappin Terraces at the Zoo; factory at West Norwood for the Telephone Manufacturing Co.; Manchester Gas Works (reinforced concrete work); Princes Theatre, Newington, S.E.; Messrs. Morton's Wharves, Lowestoft; Leach's Jetty, Tower Bridge; Stepney Borough Council, coaling island; Cleethorpes bathing pool; tunnel under Outer Circle, Regents Park; Joinville-le-pont Hospital, Paris; and Beau Desert Hospital, Bordeaux.

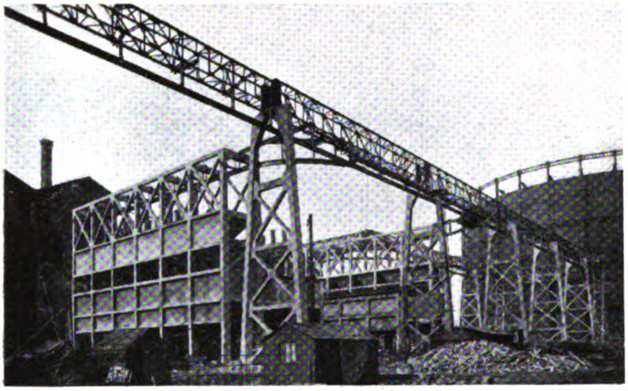


[*Simon-Carves, Ltd., R. C. Designers and Contractors.*

Washery and Bunkers for the Stella Gill Coke and Bye-Products Co., Ltd.

Standard Reinforced Concrete Engineering Co., Ltd.

Commenced business 1922. Among the principal works designed by the firm are a 7,000,000-gallon reservoir at Yeadon, Yorks, in which the apron is inclined at an angle of 60 deg. and supported by buttresses at 10-ft. centres on the base slabs—a pump house and overflow chamber are included, and water seal is obtained by a toe which projects from the bottom of the apron into the blue clay; a mill at Brighouse, Yorks, consisting of three floors and roof, supporting columns and water tower—all the floors, roof, water tower, and columns are reinforced concrete, and the area of the floors and roof is 15,075



[*D. G. Somerville & Co., Ltd., Contractors.*

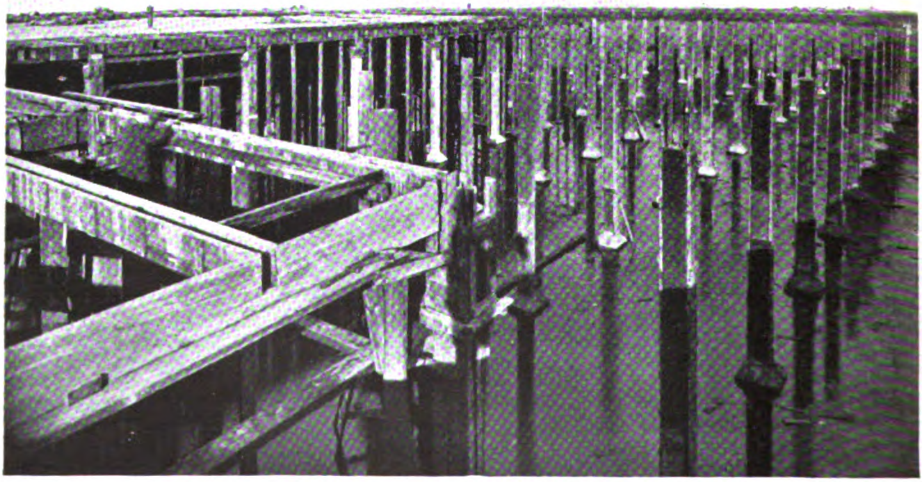
Telphers and Hoppers at Manchester Gas Works.

sq. ft. Bradford Corporation reservoir cover —the approximate capacity of this oval-shape reservoir is 5,000,000 gallons, and the surface area covered is 45,000 sq. ft.—all reinforced concrete supported on reinforced concrete columns; water tower at Middleton for the Leeds Corporation, with pump house at ground level and braced columns above supporting circular tank and a depth of water in the tank of 15 ft.; pile foundations to carry a 5-story mill at Keighley; coal bunker and ash hopper at the electric power station, York, for the York Corporation; café at Scarborough for the Scarborough Corporation—all reinforced concrete with cast-stone front; several floors and roof, with a total area of 32,970 sq. ft., at Albion Mills, Bradford; reinforced concrete picture house balcony at Bradford, to seat approximately 400 people; public baths and concert hall at Rawmarsh—the whole building in reinforced concrete except the roof over the bath; bridge at Marsden, with a clear span of 46½ ft.; settling tanks at Guiseley, for the Bradford Dyers' Association; and many other smaller mills, retaining walls, tanks, etc.

J. & W. Stewart.

Established in 1874, the firm has been particularly concerned with foundations and piling.

They were the original and sole licencees for the "Simplex" system of cast-in-place concrete piling, and in recent years have introduced into England the "Raymond" system. Reinforced concrete piling has been executed in practically all parts of the British Isles, and the following are a few typical

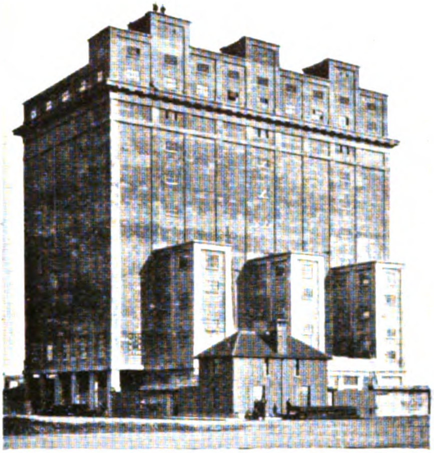


[*Standard Reinforced Concrete Engineering Co., R. C. Designers.*

Idle Hill Reservoir Cover (45,000 sq. ft.) for Bradford Corporation.

contracts: Sedimentation tanks, capacity 5-million gals., for the Belfast Corporation (including piled foundations); reinforced concrete grain silo, including piled foundations, and flour mills, in Dublin; concrete piling for slipways at Middlesbrough; excavation and foundation contracts for the new Parliament Buildings for the Northern Irish Government at Stormont, near Belfast; foundations, including "Raymond" piling, for gasholder tanks at Chester and Belvedere, Kent; foundation contract, including "Raymond" piling, culverts, etc., for the new power house for the Midlands at Stourport.

During the war the firm designed and built reinforced concrete barges at Brentford and Rochford for H.M. Admiralty, these being the first concrete barges to be classed "A1" at Lloyds as sea-going craft.



[J. & W. Stewart, R. C. Designers and Contractors.

Grain Silos at Dublin.

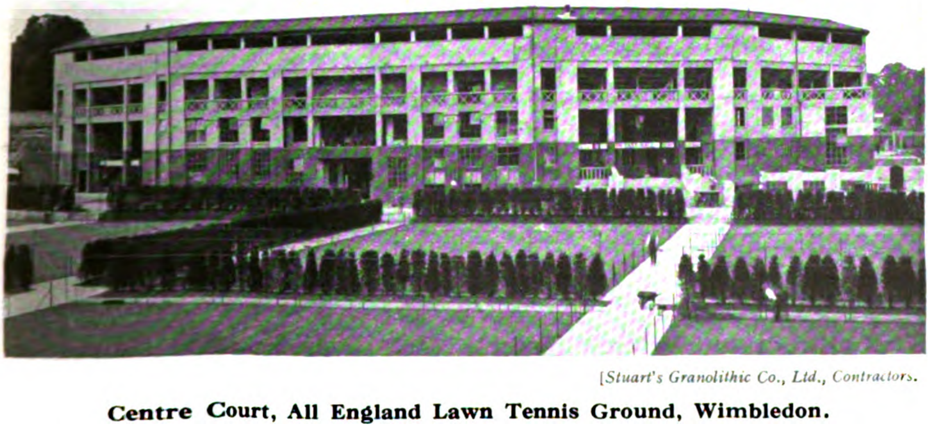
Stuart's Granolithic Co., Ltd.

Founded 1840. Specialised in granolithic paving and plain and ornamental plastering only up to 1855, since when the firm has specialised in the design and construction of all types of reinforced concrete buildings, as well as pursuing its activities in paving, staircase construction, and the production of cast-stone dressings.

As far back as the 'eighties of last century the firm carried out such works as acres of paving and staircases at Holloway College, Egham; reinforced concrete construction, paving and stairs of Selwyn College, Cambridge; reinforced concrete work at asylums at Claybury, Powick, Mapperley, Horton Manor, Longrove, Codford, Plymouth; and similar institutions throughout the country. Other works at this time included the Philadelphia City Hall, St. John's Station at Bordeaux, a large watch factory at Ivry-sur-Seine near Paris, cotton mills at Lille, and several embassies and legations abroad.

Later on paving and stairs were constructed at the Waverley and Caledonian Stations at Edinburgh and Perth General Station. The floors at the North British Railway Station Hotel and Caledonian Station Hotel at Edinburgh were designed and built by the firm, and grain silos in reinforced concrete were built at Immingham, York, Hull, Stockton-on-Tees, Selby, Birkenhead, Barry, Cardiff, Leith and London.

More recently the Royal Exchange at Manchester was reconstructed by the firm, and many buildings in reinforced concrete, such



[Stuart's Granolithic Co., Ltd., Contractors.

Centre Court, All England Lawn Tennis Ground, Wimbledon.

as the conversion of the asylum in Old Street into printing works, have been carried out for the Bank of England, and other important works include the Records Office, water towers, reservoirs for water and oil, swimming baths, tennis courts in practically every part of the country. We illustrate the Centre Court at the All-England Lawn Tennis Ground, Wimbledon, for which Capt. Peach, F.R.I.B.A., was the architect.

Tidnams, Ltd.

Founded about 1907, and owes its inception to Mr. F. H. Tidnam, of Oklahoma City, U.S.A., who handed to the Company the patented rights of his hollow ferro-concrete post. From a small workshop in Wisbech, the firm now has depots at Wisbech, Arlesey, Greenhithe, and Caerphilly, a London Office, and a Head Office at Wisbech, under the Managing Directorship of Mr. H. A. Tidnam, the original founder of the firm.

[By Tidnams, Ltd.

Cast-Stonework on a Private House.

The leading speciality of the Company is reinforced concrete fencing of all types and designs, and among the large contracts on which its products have been used are the London–Southend Arterial Road, Farningham–Wrotham Arterial Road, Sutton and Kingston By-Pass Road, Geddington By-Pass Road, Great Western Railway, London & North-Eastern Railway, London, Midland and Scottish Railway, Southern Railway, Metropolitan Water Board, Royal Estates at Windsor and Sandringham, Metropolitan Railway extensions at Watford and Rickmansworth, etc. In addition to fencing the firm carries out artificial stonework, as well as various requisites for farm and garden such as cattle mangers, pig troughs, ballustrading, etc.

Topham, Jones & Railton, Ltd.

Founded as a private firm in 1893 by the late Mr. W. H. Topham, Mr. E. D. Jones, and Mr. James Railton, and was formed into a limited liability company in 1906. The Chairman of the Company, Mr. W. H. Topham, died in July, 1924, and the present Directors are Sir Evan D. Jones, Bart., Mr. James Railton, C.B.E. (Permanent Directors), and Mr. L. G. Felkin, M.Inst.C.E. Mr. R. H. Taylor, O.B.E., who was also a Director of the Company and Managing Director for the last eight years, retired during the past year.

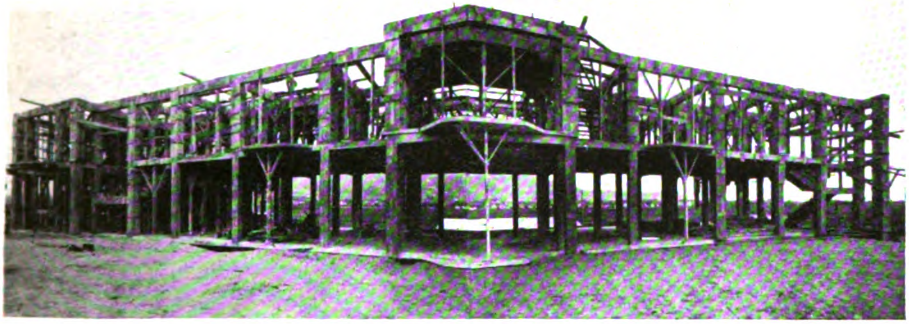
Dock and harbour contracts carried out by the Company include the Gibraltar Dockyard extension for the British Admiralty; a large deep-water dock and graving dock at Singapore for the Singapore Harbour Board; a large harbour at Prai, Penang, consisting of wharves and dredging and the Johore Causeway, for the Federated Malay Straits; the Queen Alexandra Dock at Cardiff for the Cardiff Railway Co.; The King's Dock at Swansea for the Swansea Harbour Trustees; the Empire Dock at Southampton for the London and South-Western Railway; the Tilbury Dock Extension works and the Surrey Commercial Docks improvements for the Port of London Authority; and the Fishguard Harbour Works for the Great Western Railway.

The railway contracts carried out include the Rugby to Leicester section of the Great Central Railway; the South Wales Mineral and Ogmore Valley Extension Railways in South Wales; and the Strabane to Londonderry Railway in Ireland. Other contracts carried out include dredging operations at Rosyth, Plymouth, and other places in the United Kingdom and abroad, also various railways, graving docks, quays, jetties, etc.

During the war many contracts, some of large magnitude, were carried out for the Admiralty, War Office, Air Ministry and Ministry of Munitions.

Trent Concrete, Ltd.

Specialise in the supply of aggregate and the manufacture of cast-stone. Recent contracts include: Ornamental entrance and surrounds for Lowdham (Notts) War Memorial; stone facings, decorative panels, domes, sills, steps and balcony carried on reinforced concrete beam of 35-ft. clear span, at the Picture House, Carlton; sills and coping, etc., at the General Hospital Extension, Nottingham; ashlar, sills, heads, carved panels, and name tablets, at the "Old Eight Bells" Hotel, Mansfield; stone facings, sills, carved panels, keystones, coping and name tablets, at the "Rufford Arms" Hotel, Mansfield; sills, steps, and coping, at the "Victoria" Hotel, Mansfield; steps and balustrade in white cement, for Wm. Hollins & Co., Ltd., Nottingham; string-course, sills, and coping for furniture warehouse and showrooms, at Nottingham; sills, heads, mullions, coping and pier caps, for the Turner Memorial Hall, Mansfield Woodhouse; string-courses, sills, heads for extension and gate pillars with ornamental panels for new entrance to Shipstones Brewery, Nottingham; ashlar, sills, heads and ornamental coping, at shop premises, Sutton-in-Ashfield; sills, heads and steps at a bakery at Pleasley; sills, etc., for seed warehouse at Colwick; sills, steps, ornamental heads and jambs, coping and string-courses for head offices of the Anglo-Scottish Beet Sugar Corpn., at Colwick. In addition to the above the firm has for some years supplied sills, hoods, heads, steps, larder benches, chimney caps, fence posts and all other requisites for housing schemes in various parts of the country. An example of the application of the firm's cast-stone is given on p. 56, where a cinema, for which Mr. J. A. West is the architect, is illustrated.



[*Trollope & Colls, Ltd., Contractors.*

Typical Reinforced Concrete Construction at a Large Seaside Hotel.

Triangular Construction Co.

The business of the firm comprises three distinct departments, (1) building and contracting, (2) the merchanting of concrete blocks, slabs and the like made in the Company's factory, and (3) the manufacture of machinery for concrete products. The business was started in 1919, specialising in the "Triangular" system of construction, and among the larger buildings executed in this system are the Metropolitan Police Training Establishment, Thames Ditton; County Hall Annexe, Kingston-on-Thames; boarding school at Datchet; Messrs. Kelly's Paper Mill, Kingston-on-Thames; automobile works, Egham; Seamen's Hospital, Tilbury, comprising new wards and nurses' quarters; four-story factory at Nottingham; depot and stables for Southall-Norwood U.D.C.

The Company's activities have also been directed towards the erection of houses varying in price from £350 to £3,000 each, including the following:—Tilbury housing scheme (700 houses); Esher and the Dittons housing scheme (86 houses); Imber Court Estate (44 houses); Haslemere housing scheme (20 houses); Beddington and Wallington housing scheme (28 houses); East and West Molesey housing scheme (29 houses).

In addition, numerous contracts of from £1,000 to £3,000 in value are being carried out in various localities. The Company now manufactures triangular blocks and "Trianco" slabs, and roofing tiles. Three large depots are in existence, and arrangements are being made for opening depots throughout the country.

The Company manufacture "Trianco" machines for blocks, slabs and tiles, and they have already done very considerable business in connection with the sale of these machines to manufacturers of the products, in addition to builders producing their own material. A recent innovation is the introduction of a machine for erecting triangular blocks, and which it is proposed to adapt for the erection of ordinary bricks and other types of blocks; we are informed this machine has attained a speed equivalent to 15,000 ordinary bricks per day.

Trollope & Colls, Ltd.

Historically, the Company is interesting, consisting as it does of the amalgamation in 1903 of the firm of George Trollope & Sons—

which commenced business in Westminster in 1778—with the City firm of Colls & Sons—established in 1840. Many of the fine buildings which now adorn historic streets throughout London stand as a record of achievement of the firm, the list including buildings for many of the largest banks, insurance companies, industrial undertakings, factories, hotels, restaurants, and clubs. It is also of interest to note that important contracts have been successfully carried out by the Company in the Far East, such as the Hongkong & Shanghai Bank, the Chartered Bank of India, Australia and China, and the Yokohama Specie Bank in Shanghai; the Government Fire Station and Post Office at Hongkong; public works in Japan, etc. In 1912 the Company organised an Engineering Department—under the direction of Dr. Oscar Faber, who relinquished his position as Chief Engineer to the Company in 1921, and was succeeded by Mr. G. B. Brader—to undertake the design and construction of all kinds of work in reinforced concrete and structural steel, and for dealing with the special problems and difficulties which arise in connection with building work on a large scale. Since its inception the Engineering Department has carried out a large number of contracts, both in London and in the provinces, and the following list of types of reinforced concrete work may be cited as illustrations of the varied character of the work:—Railway viaducts and bridges, coal bunkers, reservoirs, concrete roads, grandstands, factories, and fire-resisting floors.

[*Trussed Concrete Steel Co., Ltd., R. C. Engineers.*

Building for Napier Motors, Ltd., Acton.

Trussed Concrete Steel Co., Ltd.

This Company, designing on the "Kahn" system, was formed some twenty years ago. The factory building is a question of great importance to manufacturers, and a very large percentage of the best-known industrial concerns in this country have adopted reinforced concrete. The firm has acted as reinforced concrete engineers for model daylight factories built on the Kahn system of reinforced concrete by the following firms:—Birmingham Small Arms Co., Ltd.; Vickers, Ltd.; Daimler Co., Ltd.; British Westing-house Co. (now Metropolitan-Vickers, Ltd.); Albion Motor Car Co., Ltd.; Price's Patent Candle Co., Ltd.; G. & J. Weir, Ltd.; Reckitt & Sons, Ltd.; General Electric Co., Ltd.; Nestles; Vauxhall Motors, Ltd.; Dunlop Rubber Co., Ltd.; Bradford Mills; Affleck Mills; Imperial Paper Mills; Arrol-Johnston, Ltd.; Bowden Brake Co., Ltd.; Kodak Company; The Matchless Motor Works; Woolcombers, Ltd.; Leyland Motors, Ltd.; Belsize Motors, Ltd.; Chas. Macintosh & Co., Ltd.; D. Napier & Sons, Ltd.; Tilling-Stevens, Ltd.; Thomas Firth & Sons, Ltd.; British Oil & Cake Mills, Ltd.; Apsley Mills; Dyehouse Mills; Cape Hill Brewery; Commercial Cars, Ltd.; Components, Ltd.; Ford Motor Co.; Metropolitan Car Co.; Gramophone Co., Ltd.; Houghton-Butcher Co.; Maconochie Bros., Ltd.; Austin Motors; etc.

This Company has also been active in bridge construction, as the following selection of bridges constructed on the "Kahn" system will show:—Bridge at Woodbridge, Guildford; Ponteland Bridge, Northumberland; Stranmillis Bridge, Belfast; Wergins Bridge, Hereford; Ringwood Road Bridge, Dorset; bridge at Thorverton, near Exeter; 2 bridges, Barrow-in-Furness; Bush Hill Park Bridge, Alperton River Bridge, Dukes Bridge, and Sudbury Spur Bridge, for the Middlesex County Council; Princes Bridge, for the Leamington Corporation; 2 bridges over the Thames, at Goring and Streatley, for the Berkshire and Oxfordshire County

[*Trussed Concrete Steel Co., Ltd., R. C. Engineers.*

Motor Works at Dumfries for Arrol-Johnston, Ltd.

Councils; Pymmes Brook Bridge, North Circular Road; Pymmes Brook Bridge, Turkey Street Bridge, and Salmon's Brook Bridge, Cambridge New Road; Chandlers Bridge, Lymington; bridge over the Grand Junction Canal, Hayes; Longford River Bridge; Greenford Bridge; Great Bath Road bridges for Berks. County Council. An interesting present-day contract is the Albert Bridge, Windsor, over the Thames, now being built to a design approved by H.M. the King.

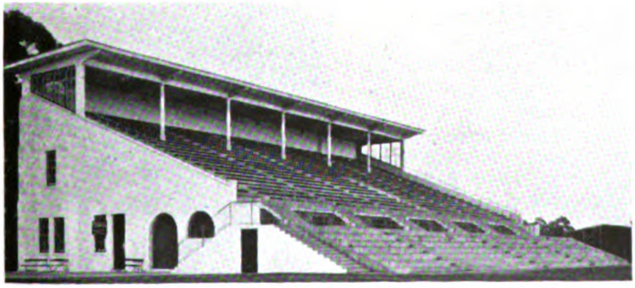
In big engineering projects the "Kahn" has been adopted for such schemes as:—Naval Base, Rosyth; Immingham Docks; Admiralty Jetty, Firth-of-Clyde; dock shed for the Mersey Dock and Harbour Board; Southampton Town Quay; Carnarvon Sea Wall; wharf at Stockton-on-Tees, for Craig, Taylor & Co., Ltd.; Oil Jetty at Belfast Harbour.

In addition to a large number of warehouses, water towers, bunkers, reservoirs and tanks, evidence of the "Kahn" system may also be found in such well-known public buildings as the National Gallery; the Tower of London; the Central Hall, Westminster; the Royal Exchange, Manchester; and the Cunard Building, Liverpool. Mention may also be made of the circular stand erected for the International Lawn Tennis Championships at Wimbledon (illustrated on p. 143), which is possibly the most imposing structure of its kind in Europe and has a seating accommodation for 12,000 people.

The Company are also the patentees of the "Truscon" floor in reinforced concrete, and of "Hy-Rib" metal lathing. The former has been adopted for such buildings as Adelaide House, London Bridge; Cook's new building, Berkeley Street; Devonshire House, Piccadilly; New India Building, Liverpool; general hospitals at Lewisham and Nottingham; and many others.

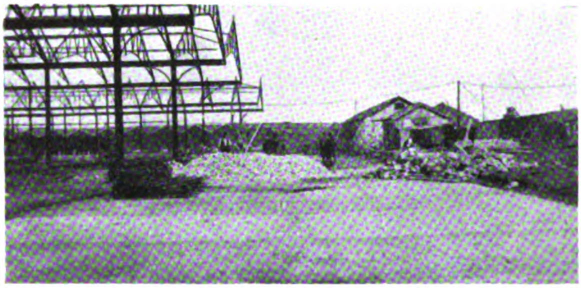
The Walker-Weston Co., Ltd.

Commenced business in 1919, and have carried out contracts comprising the construction of concrete surfaced roads, and the supply of reinforcement to various public bodies and Corporations, some of the more important contracts being as follows: Walthamstow Borough Council; Manchester Corporation; Middlesbrough Corporation; East Ham Corporation; Flintshire County Council; Belfast Corporation; Sheffield Corporation; Hull Corporation; Essex County



[*Trussed Concrete Steel Co., Ltd., R. C. Engineers.*

Grand Stand at Kenilworth, South Africa.



[*Walker-Weston Co., Ltd., R. C. Designers.*

"Inverted" Reinforced Concrete Road for the Port of London Authority.

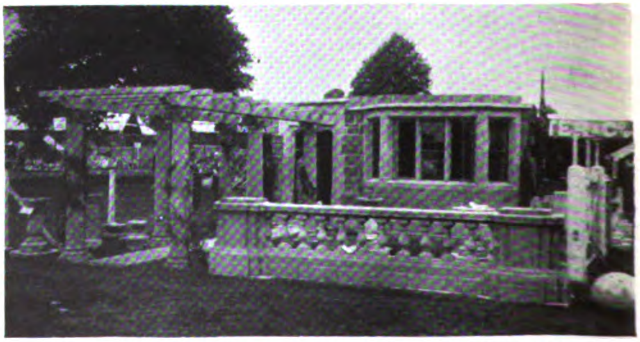
Council; the Port of London Authority, Harland & Wolff, Ltd., and various public works contractors.

The Company specialises in the construction of concrete surfaced roads, laid on the alternate bay system, with interlocked expansion joints and large aggregate in the surface layer. Our illustration shows an inverted concrete road recently constructed.

Wharf Lane Concrete Co., Ltd.

Commenced business in 1920, manufacturing general concrete products, and executing contracts for fencing posts, curbing, sewer pipes, etc., for the Devon, Dorset, Somerset, and Wilts County Councils and also Urban and Rural District Councils in the area. The firm's concrete fittings for farm buildings have been installed in some of the largest West Country estate and dairy farms, including Barrington Court Estate, Dillington Estate, Earnshill Estate, Wilts County Council, Sir Charles Miles's Estate, Chard Cooperative Farm, and Messrs. Harris & Co.'s Farm at Calne.

The Company specialises in cast stone reproductions of natural stone, particularly Ham stone, which has been used at Sherborne Castle, Broadwindsor House, Watts House, Leigh House, Jordans House, Gerbeston Manor, Whitestaunton Manor, Langdon Manor, The Hyde, Bridport, and many other mansions in the district. Among other buildings in which the firm's cast stone has been used are memorial halls at Sherborne, Ilminster, and Merriott; memorial at Whitelackington, Ilminster; Wesleyan Church at Whitchurch, Hants; Congregational Church at Ilminster; business premises at Axminster, Bridport, Taunton, and Kingston Vale; bridges at Witney (Oxford)—reconstructed from the actual stone from the old bridge; houses at Pelsall, Charmouth, Bagborough, etc.; sports pavilions at Crewkerne and Ilminster; and paving for Wells Cathedral.



[*By The Wharf Lane Concrete Co., Ltd.*

Ornamental Concrete Work.

Yorkshire Hennebique Contracting Co., Ltd.

Founded twenty-five years ago by the present Managing Director, Mr. David Jones, and traded as D. Jones & Co. The present company was registered as a private limited company in 1904, under its present title.

The Company makes a speciality of piling work, and was one of the pioneers in making and driving of ferro-concrete piles. Amongst the piling contracts carried out are: Loughor Bridge (720 ft. long); King George Wharf and Extension; Extension to Quay, Princess Dock, Liverpool; Viaduct for the Great Southern and Western Railway of Ireland (length 720 ft.); Jetty at Bridgend; Firgrove Bridge, near Rochdale; bridges at Ashton-under-Lyne, for the L. & Y.R. Co. and G.C.R. Co.; 7 gantries to coal hoist at Immingham Dock; Tuckton Bridge, Christchurch (353 ft. long); pile foundations for new G.P.O. at Hull, and Caird Hall, Dundee.

Buildings include Foundations and superstructure of Caird Hall, Dundee; of Armley High School, Leeds; Shop and office premises, Lion Buildings, Glasgow; Grain stores and jetty at Waterford; Almond Block, York, for Rowntree & Co.; Warehouse at Bradford; Spinning mill at East Ardsley; Warehouses for the Imperial Tobacco Co.

[*Yorkshire Hennebique Contracting Co., Ltd., R. C. Engineers and Contractors.*

Loughor Bridge (720 ft. long by 35 ft. between Parapets.

Reservoirs and miscellaneous works include Colliery headgears at Skelmanthrope, Tingley, Chidswell, Plean Colliery (Stirling), and Doncaster; Cement silos at Southam; Grain silos at Leith and Ordsall Dock (Manchester); Coal washery at Lincolnshire Steel Works; Rheolaveur washery, Mansfield; Stone bunkers at Penzance; Swimming baths at Dundee and Cudworth; Reservoir at Leicester, 5-million gallon and 1-million gallon capacity; numerous water towers, jetties, etc.

A New Light-Weight Concrete.

A NEW concrete of the "expanded" type has been put on the market by Messrs. Christiani & Nielsen, of 74, Victoria Street, S.W.1. This material, which is of cellular construction, contains throughout its mass innumerable air-pockets formed by the admixture of a foam of a specially-prepared liquid into a mortar of finely-ground cement and sand. In addition to its extreme lightness, the material has high insulating properties owing to the large proportion of air cells; it is weatherproof and practically non-absorbent of moisture; and is also fireproof and rustproof. It is on account of its lightness and insulating properties that this material will mostly appeal to the architect and engineer. According to the amount of foam added to the mortar the weight can be controlled, but for practical purposes it is at present being manufactured in weights varying from 16 lbs. to 75 lbs. per cubic foot. The insulating properties naturally vary with the specific gravity of the material, being highest in the case of the lightest concrete. Tests have shown that the coefficient of thermal conductivity which penetrates in 1 hour through 1 sq. ft. of the material (1 cement to 3 sand), 1 ft. thick, weighing about 40 lbs. per cubic foot, is 0·123; while with material weighing about 65 lbs. per cubic foot the coefficient is 0·117. Thin walls of this material (which is called "Cellolit") are thus greatly superior to ordinary building materials in the protection they give against changes of temperature. Tests have shown that the material is unaffected by freezing, or other extremes of weather conditions. The compressive strength varies, of course, according to the density; thus a concrete weighing 25 lbs. per cubic foot has a bending strength of 400 lbs. per sq. in.; and a concrete weighing 62·4 lbs. per cubic foot has a strength of 900 lbs. per sq. in. In building construction this new concrete is generally used in the form of blocks and slabs, although if desired it can be poured *in situ*, and its lightness enables large blocks to be easily handled. The surface finish is quite even except for the air cells, which give a good key for plastering. The uses for such a material are multitudinous, such as flooring, walling, covering for steelwork, insulation of tanks, pipes, etc., and general cold storage purposes. It is covered by world patents.

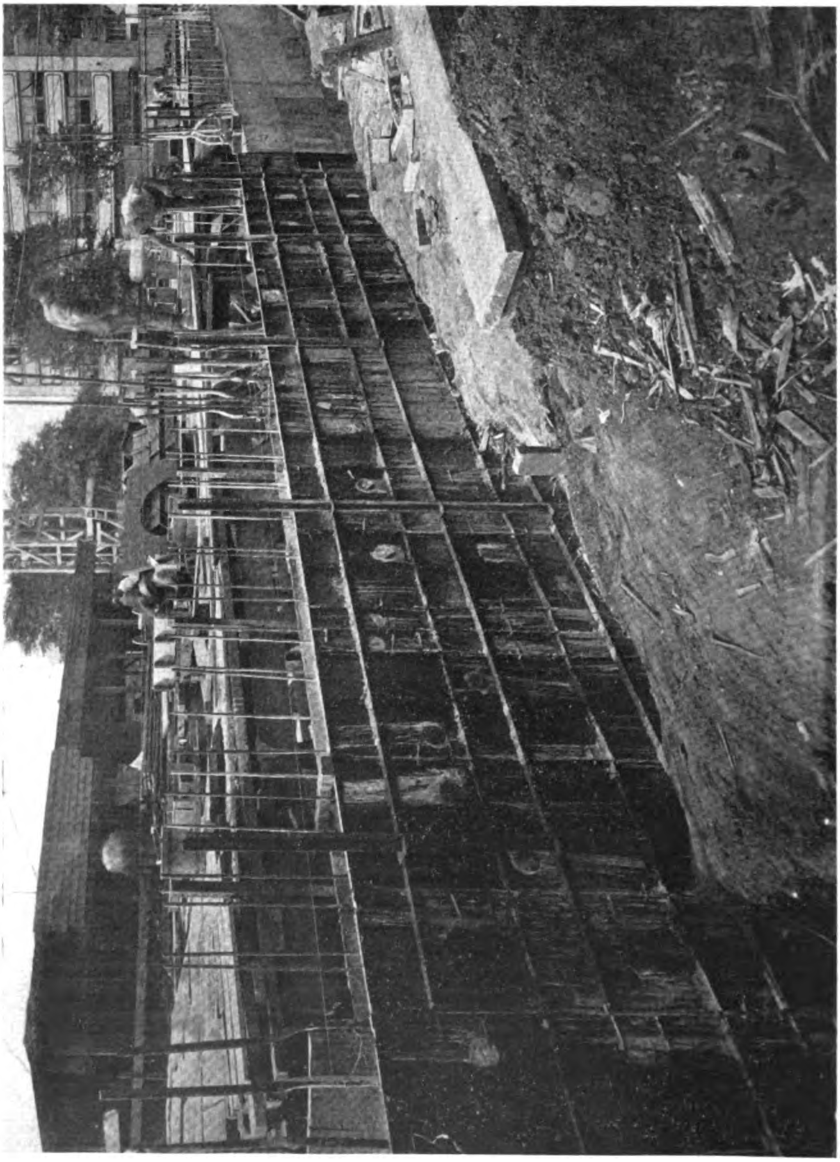


FIG. 124.—"BLAW-KNOX" LIGHT WALL FORMS.
(*See p.* 151.)

Design of Formwork for Reinforced Concrete Construction.

By A. E. Wynn, B.Sc., A.M.Am.Soc.C.E.

XVI.—STEEL FORMS IN BUILDING AND WALL CONSTRUCTION*

THE use of steel forms has increased rapidly in the past few years. They can now be obtained for any type of structure and of any shape, and have replaced wooden forms almost entirely for certain structures. Their economy depends, of course, on the number of times they can be used. It would not be economical to buy steel forms for a job on which they could only be used two or three times, unless the contractor could move them from one job to another. They should be regarded more as plant than material, and the same considerations should govern their purchase as with a piece of plant. Interest on investment, depreciation, upkeep, storage, handling, freight charges, etc., should all be considered in addition to first cost. As with any other plant, to be economical they must be in constant use.

Where a job is sufficiently large steel forms will usually more than pay for themselves on the one job, even when perhaps owing to special construction they cannot be used in other work. Steel forms can be hired instead of bought outright, though this practice is much commoner in the United States than in this country. The rental will usually amount to about 70 per cent. of the purchase price, though this depends on the length of time used. If hiring can show a saving over wood forms, even considering the salvage value of the timber, it may be the best policy, since the next job on which they could be used is always uncertain and storing is not profitable.

Besides the first cost, there is the question of the saving of labour in erection and stripping. This is considerably less with steel forms than with wood forms, and it is this saving of labour cost that will decide whether steel forms are economical or not. Steel forms arrive on the job ready to place, without the preliminary work required with wood forms, so that the time and labour spent in making-up the forms is saved. The methods of connecting panels, bracing, and tying being already provided for, erection is almost mechanical and requires no special skill and may be done by common labour, so that the cost of erection and stripping will be much less than for wood forms. Better work can be done, as the forms are factory-made and fit exactly.

Labour cost can be more accurately estimated with steel than with wood forms, since it is more of a mechanical operation and the "personal equation" does not enter into account so much. The labour cost of wood forms may vary considerably on two similar jobs using different carpenters and foremen.

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* Parts XII to XV of this series have been omitted, and will be published later, together with the Parts which have appeared in *Concrete and Constructional Engineering*, in book form.

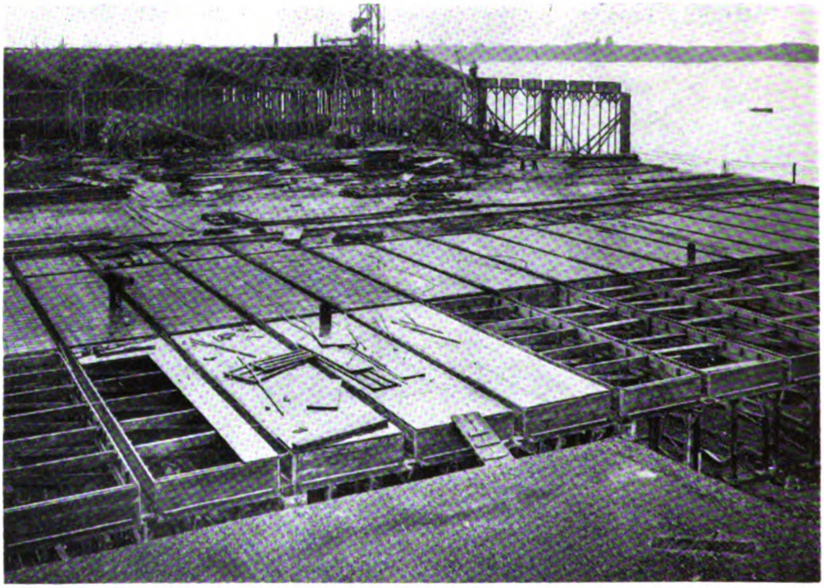

FIG. 121.—"DESLAURIER'S" STEEL SLAB FORMS USED IN BEAM AND GIRDER CONSTRUCTION.

Other advantages of steel forms are smoother surfaces, requiring very little re-touching, denser surfaces and hence less absorption of paint, and the smaller number of men required.

It is therefore not always a simple matter to compare the relative economy of steel and wood forms, as there are so many items that should be taken into account for a true comparison. They can be obtained for any type of structure, and through all degrees of complexity from the simple light wall panels to the huge structural steel travelling forms used in dock-wall construction.

Although a contracting firm may design its own steel forms and have them made to order, it will usually prove more economical to buy them from the firms that specialise in their manufacture and who have had years of experience in their use. The forms manufactured by these concerns are of course patented. It would serve no particular purpose to describe the detail construction of the forms, since this can be obtained from the manufacturers, who will also advise the best type of form to use for a particular structure. Instead, by giving photographs of actual construction work in which they have been used, the multitudinous uses to which they may be put are shown.

It is convenient to divide steel forms into two groups, those for forming flat surfaces and those for curved surfaces. The former only will be considered in this chapter.

Buildings.—Steel forms for round columns and caps and for deck panels in flat slab construction have already been mentioned, as also have metal tile fillers, which are really steel forms. These are the commonest uses for steel forms in building construction.

Steel slab-panels for beam and girder construction have been used to some extent, in combination with wood beam boxes. Slab-panel forms manufactured by the DesLauriers Column Mould Co. are shown in Fig. 121 (note also the method of supporting the forms for a saw-tooth roof). Steel has not yet taken the place of timber for shores, joists, ledgers and beam sides. The only other extensive use of steel forms in buildings is for foundation and other concrete walls.

Light Wall Construction.—Light wall panels are 24 in. square, made of sheet metal with angle-iron stiffeners, fastened together by clamps, wedges, spikes, etc., according to the system used. They are made in standard sizes so that any length of wall may be formed, adjustable panels taking care of odd inches and fractions of an inch, and special corner pieces are provided. The usual method is to use two or three courses, one above the other, pouring 4 ft. or 6 ft. the first day and 2 ft. or 4 ft. on succeeding days, the forms being stripped in twenty-four hours. Using two courses, after the first two courses are filled the lower course is stripped and placed on top of the second course, forming the third course, and the second course forms the fourth course, and so on, one course always remaining in contact with the concrete to support the course above.

In the "Metaform" system the units are connected together with clamps. Using only two courses wales are not necessary but they add to the rigidity of the form and facilitate the aligning. When more courses are used, adjustable steel aligners are clamped to the forms, a horizontal aligner to each plate and vertical aligners 8 ft. to 10 ft. apart. The

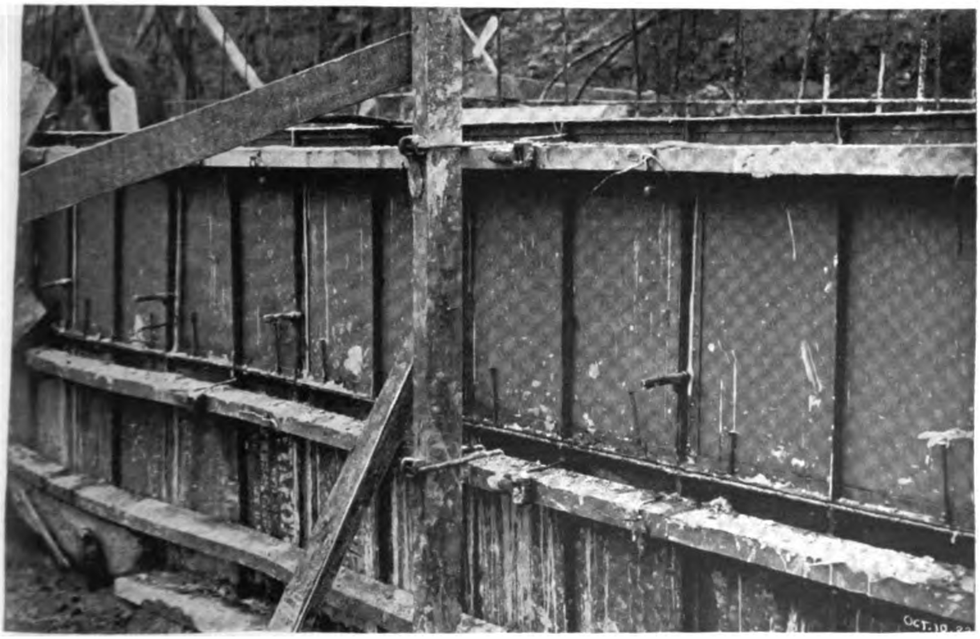

FIG. 122.—"METAFORMS" WITH WOOD WALES.

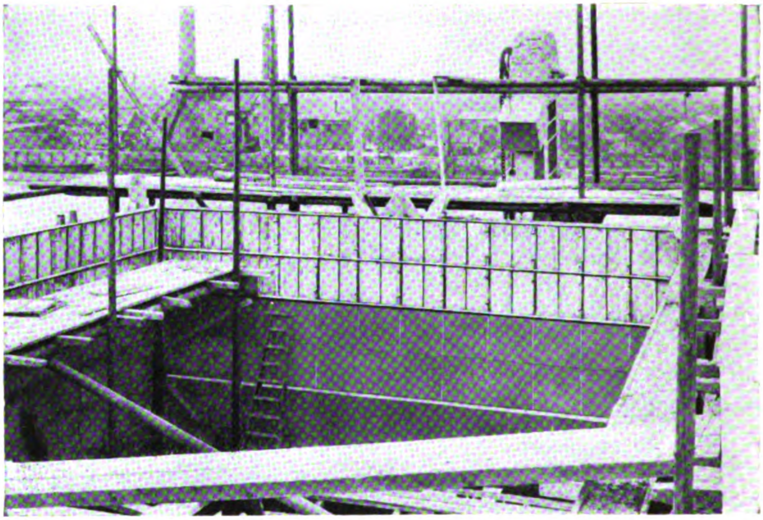

FIG. 123.—" METAFORMS " WITHOUT WALES.

aligners are made to telescope so that they can be adjusted to different lengths. Instead of steel aligners, ordinary 2's by 4's can be used with the same clamps. *Figs.* 122 and 123 show the use of " Metaforms " in light wall construction, with and without aligners.

In the " Blaw-Knox " system, Blaw light wall forms are connected together with wedges driven into corresponding slots in adjacent units. Angle-iron wales are dropped into slots on the panels, and vertical aligners are attached to these with wedges (*Fig.* 124). Steel bulkhead panels are provided.

Using the aligners with both systems enables a wall to be built to a height of 10 ft. at one pour, and also enables several panels to be moved as a unit, instead of one by one. In each system wire ties are used to prevent the forms from spreading, and metal spacers on the top course keep the forms the right distance apart.

The Blaw-Knox Co. manufacture angle-iron yokes which slip over and hold two courses of forms, if the use of wire ties is objectionable owing to the possible appearance of rust spots. The same company also manufacture a hand-operated machine for making the wire ties quickly and uniform.

It is essential that the footing on which the first course is set be level. No outside bracing will be necessary. The work of placing the forms can be done by common labour. The workmen should work in pairs, one placing the outside panels and one the inside panels, the former working a little ahead of the latter.

The forms should be cleaned and oiled every time they are stripped, including the last stripping, even if they are not to be used again for some time. Remembering that they are part of a contractor's plant, they should have the same care.

Heavy Wall Construction.—On large contracts where there are heavy walls, as in docks and canal locks, and for heavy retaining walls, steel forms are particularly useful and economical. These contracts are usually so large that the first cost of the forms is less important than the saving in labour cost, and for that reason it is often economical to have steel forms specially designed and built for a particular purpose.

The method of raising one course above the other used in light walls would be entirely too slow and uneconomical on large work, so instead the walls are built in vertical sections about 30 ft. long, pouring the wall in one, two, or three operations. This means that very heavy bracing is required, and that the bracing must generally be from the outside owing to the large width of the wall.

Figs. 125 to 132, showing the varied use of heavy steel wall forms, are given by courtesy of the Blaw-Knox Co., of Pittsburgh, U.S.A. The forms may be designed as stationary or travelling. In the former case they are built up into units of such a size as can be conveniently handled by the plant available. A unit may consist of the forms for one side of the wall only, or for both sides.

In *Fig.* 125 is shown a form for a heavy railroad retaining wall, which is designed to be lifted in one piece and is also adjustable to various

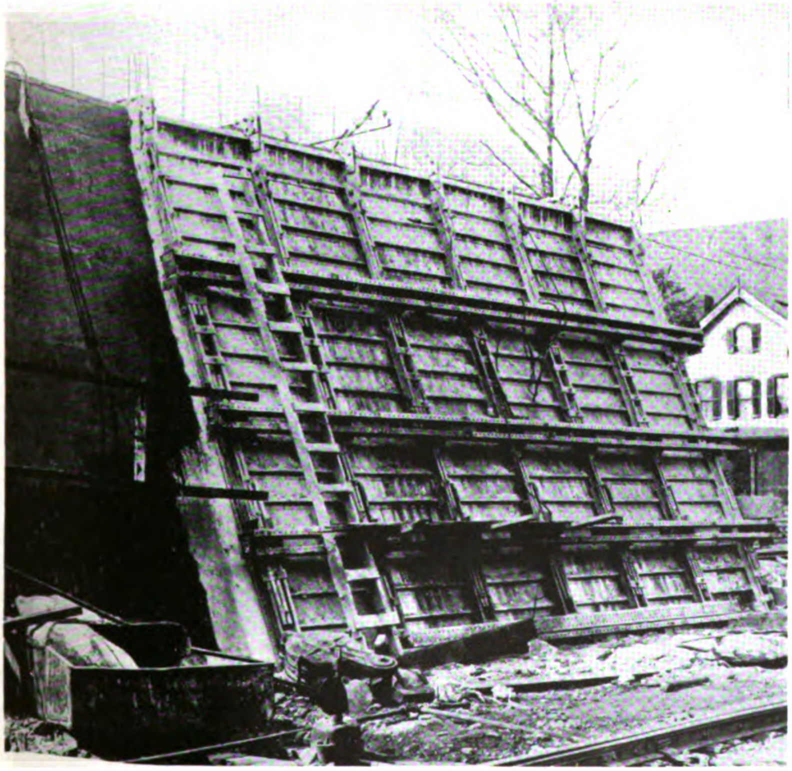

Fig. 125.—Forms of Railway Retaining Wall, Designed to be Lifted in One Unit.

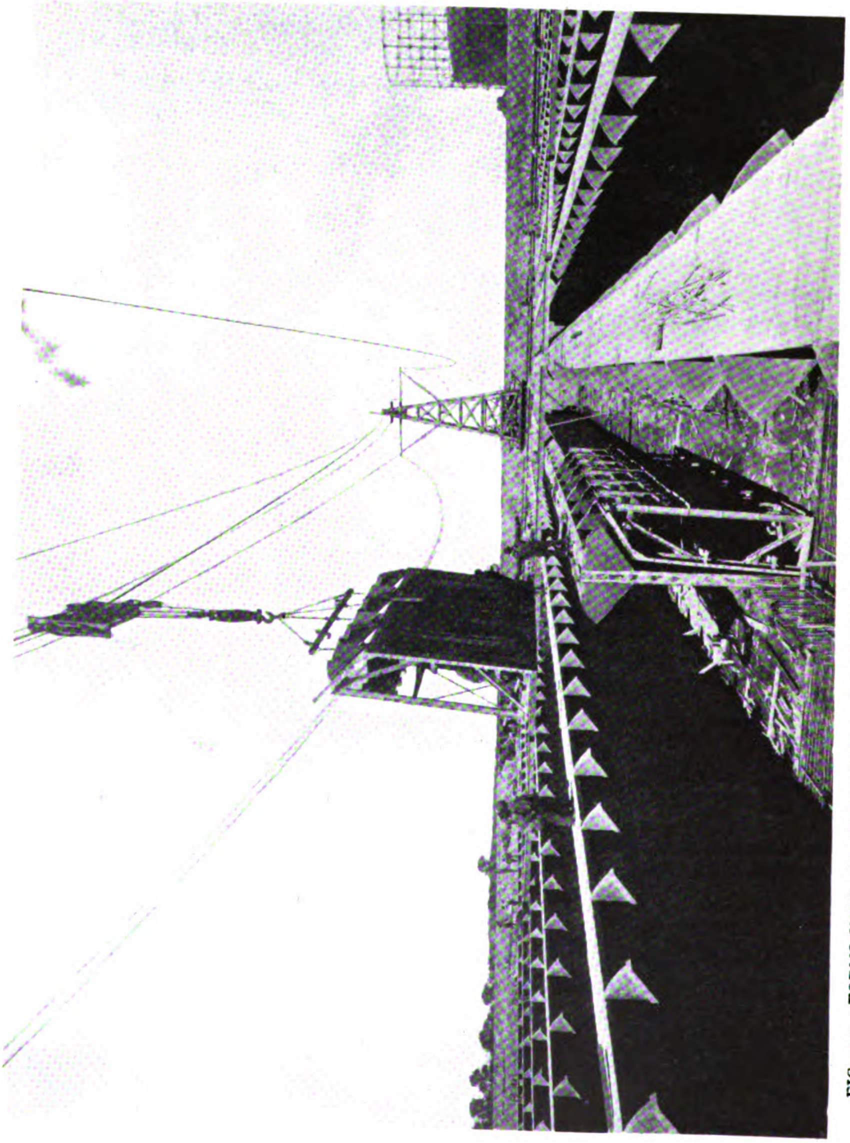

FIG. 127.—FORMS USED IN CONSTRUCTION OF SEWAGE TREATMENT WORKS: FORMS HANDLED BY CABLEWAY.

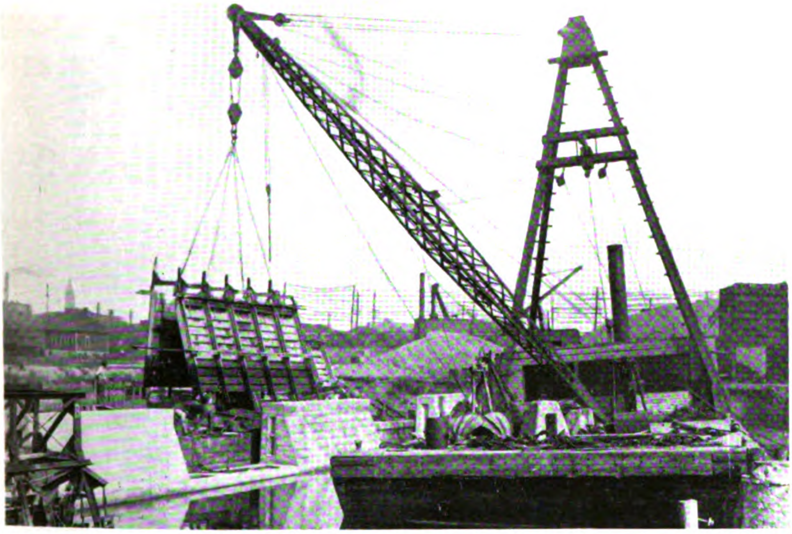

FIG. 126.—FORMS FOR A DOCK WALL: BOTH SIDES MOVED AS ONE UNIT.

types of wall. *Fig.* 126 shows forms for both sides of a dock wall being lifted as one unit by a derrick.

Fig. 127 shows forms for high thin walls with brackets at the top being lifted in units by a cableway. These forms were used in the construction of the Chicago Sewage Works. (Note the method of bracing the forms, and the large area of walls on which they were used.)

Instead of lifting the forms up bodily they may be designed to slide along horizontally. In this case they are attached to a structural steel frame called a "traveller." A unit of forms consisting of back and front forms may be attached permanently to the traveller, or the traveller may be detached and handle several units in turn. In the former case the traveller also braces the wall, while in the latter the wall forms are self-supporting. The travelling frame usually straddles the wall and moves on rails. The forms are collapsed by jacks, turnbuckles, or steamboat ratchets. The traveller with forms attached is moved by hand power for small installations and by winches for the larger jobs. For still heavier forms gasoline, steam, or electric hoists are used.

Fig. 128 shows wall forms for an ore dock. The high traveller is independent and handles eight sets of forms. *Fig.* 129 shows forms used in the construction of a seawall in Florida. One hundred and fifty feet of wall forms and 50 ft. of traveller were used, the forms being self-supporting and the traveller being only used to move them by means of the winch shown. The ratchets are shown hung up out of the way, the traveller being ready to move back on the rails to pick up another section.

In *Fig.* 130 the forms and traveller form a single unit. The wall being very high, it was poured in two lifts as there was possibility of the

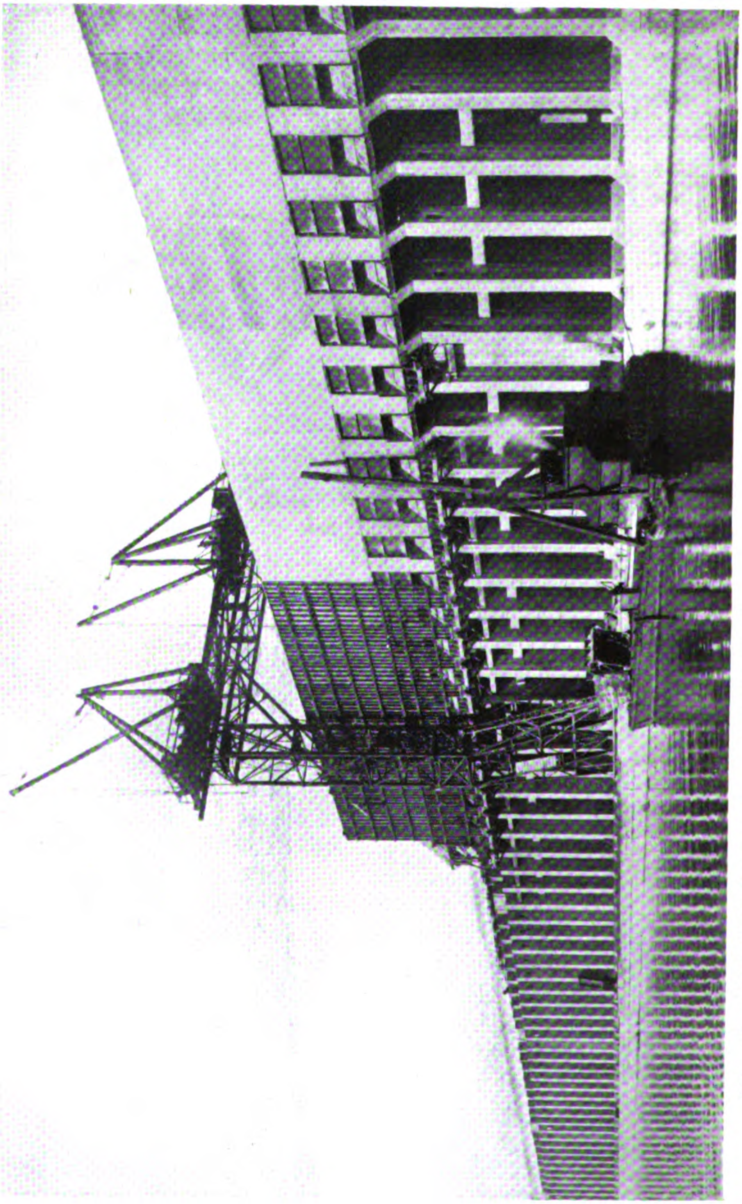

FIG. 128.—HIGH TRAVELLER HANDLING INDEPENDENT PANEL FORMS IN CONSTRUCTION OF ONE DOCK.

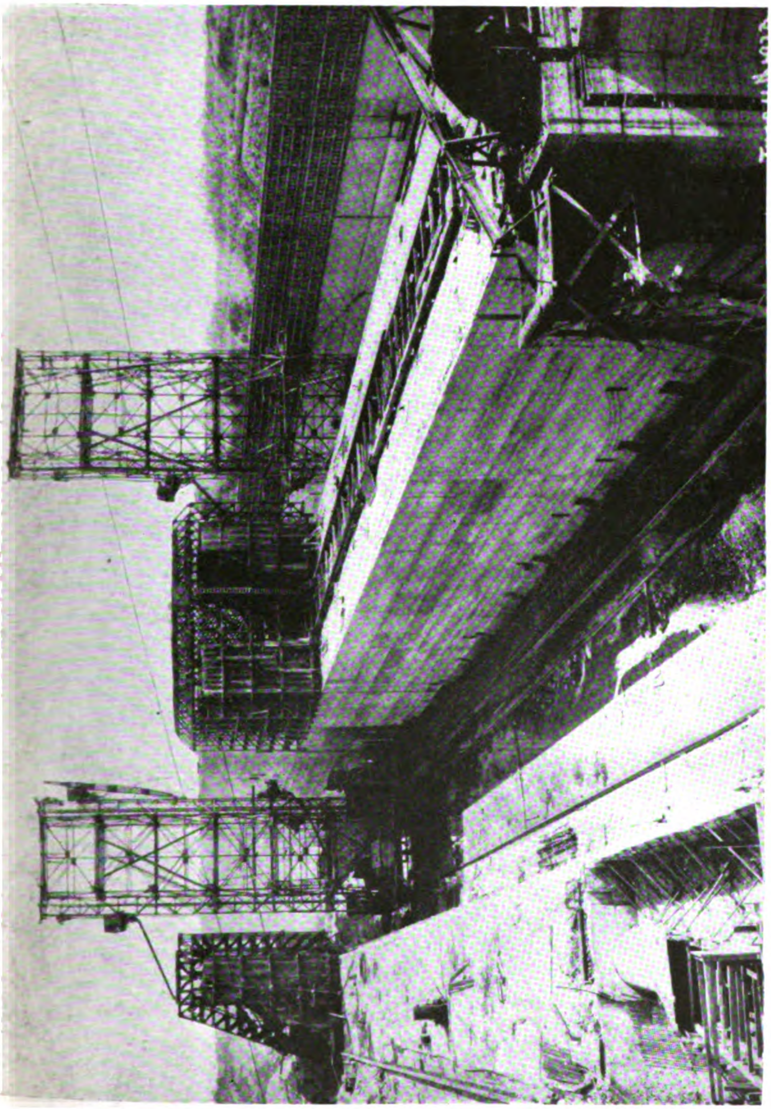

FIG. 131.—TRAVELLING WALL FORMS USED IN CONSTRUCTION OF WELLAND CANAL.

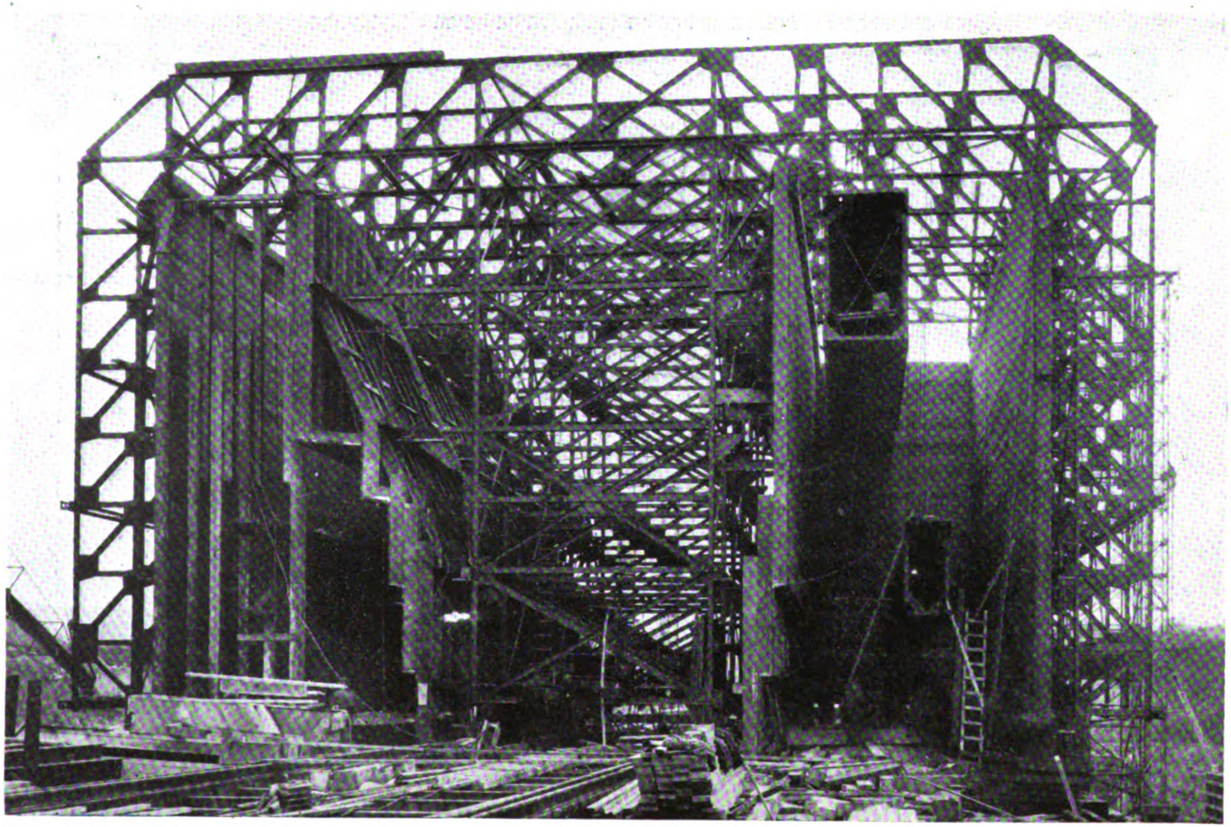

FIG. 132.—DOUBLE TRAVELLING FORM USED IN CONSTRUCTION OF WELLAND CANAL: NOTE SUSPENDED CULVERT FORMS IN RIGHT-HAND WALL.

form being blown over if assembled to its full height. The wall being constructed is for a penitentiary.

Figs. 131 and 132 show extremely heavy travelling wall forms used in the construction of the Welland Canal. The main forms are of steel framework with wood lagging. In the right-hand wall shown in *Fig.* 132 are seen two suspended steel culvert forms. These two pictures show that there is no size of wall too large for the use of steel forms, and also show the saving in time and labour by having the forms attached to a traveller so that they can be easily and quickly stripped and moved ahead.

Estimating Cost of Light Wall Forms.

The method of erection is so simple that unskilled labour can handle the forms after a little instruction.

To erect complete and strip 100 sq. ft. of wall forms—contact area—should not require more than six hours of labourers' time. This is for unskilled labour, and should be a maximum. Men experienced in erecting these forms should perform the same amount of work in about half the time, but their rate of pay will be higher.

It will require about the same labour to strip and oil as to erect and wire-up. The same amount of wire ties will be required as for wood forms.

Comparing with the costs given in Chapter VIII, it will be seen that the labour cost on steel wall forms should not be greater than one-third the labour cost of wood forms.

A comparison of the first cost of steel forms with wood forms is more

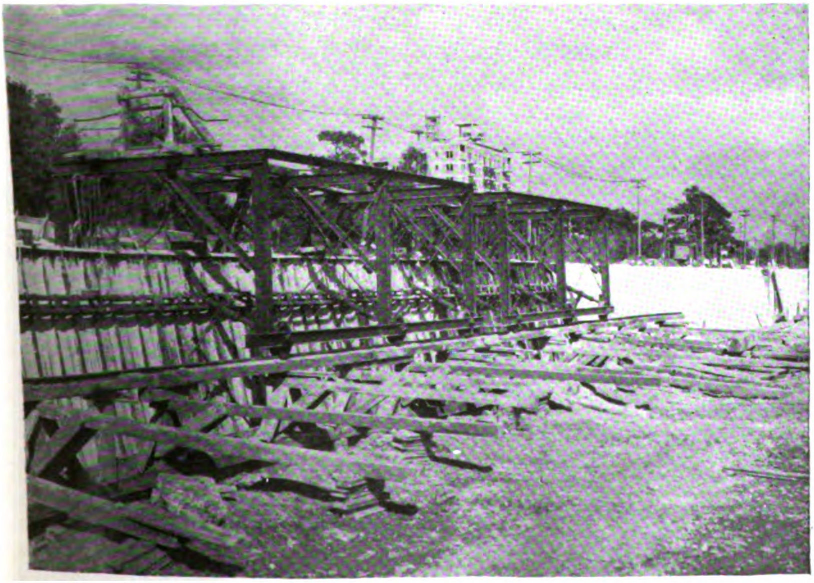

Fig. 129.—Fifty Feet of Traveller Handling 150 Feet of Forms in Construction of Sea Wall.

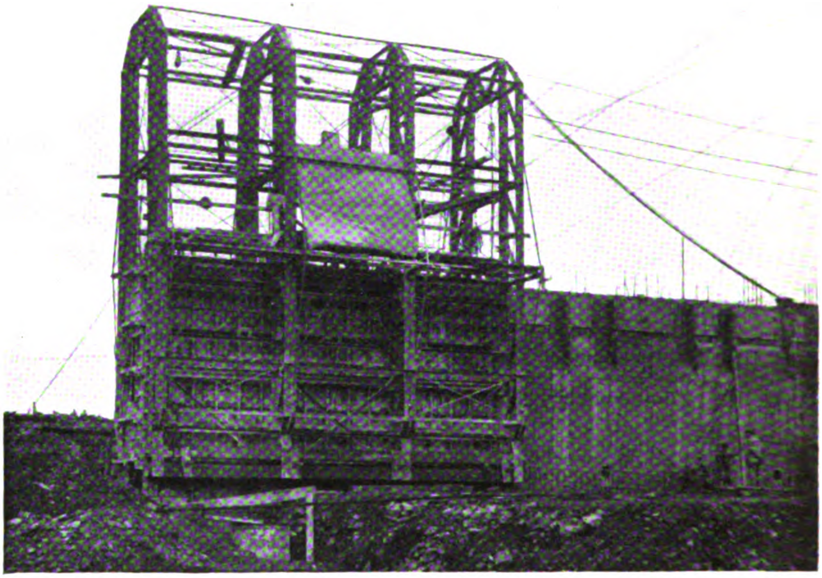

FIG. 130.—TRAVELLER AND FORMS FORMING A SINGLE UNIT: WALL POURED IN TWO LIFTS.

difficult to make. At the present time light steel wall forms will cost 8 to 10 times as much per sq. ft. as will the necessary amount of timber per sq. ft. of wall, but usually less area of forms is required when steel forms are used.

If the steel forms are carried as plant the whole first cost would not be charged to one job, probably not more than 25 per cent.; that is, the cost would be distributed over at least four jobs. Hence, taking into consideration the saving in labour, steel forms compare very favourably in cost with wood forms. Even if the whole cost is charged to a particular job steel forms will often be more economical providing they can be used over a sufficient number of times, so that the saving in labour will be more than the difference in first cost.

"THE CONCRETE YEAR BOOK."

THE 1926 Edition of "The Concrete Year Book," edited by Dr. Oscar Faber, O.B.E., D.Sc., M.Inst.C.E., and H. L. Childe, is now ready. This edition, extended to over 400 pages, has been thoroughly revised, and a great deal of new matter of everyday use to all connected with the concrete industry has been added. Those who wish to make sure of securing a copy are advised to place an order early in order to avoid disappointment, as in spite of large printing orders previous editions have always been exhausted. In addition to the mass of useful data in the Handbook Section, the volume contains the only complete Directory of every branch of the concrete industry and a Catalogue Section of over 200 pages giving full particulars of all the chief items of machinery, plant, products and materials used in the industry. Although the volume has further increased in size the price remains the same at 2*s*. 6*d*.

Our Illustrations.

For the illustrations in this issue we have to express our indebtedness and thanks to several sources.

The Trussed Concrete Steel Co., Ltd., kindly supplied us with the photographs of the Tillings-Stevens building at Maidstone, and the Sandhurst Memorial Chapel, for which buildings they designed the reinforced concrete.

The sun shelter at Ramsgate was designed in reinforced concrete on the Coignet system. The reinforcement was composed of round bars of mild steel varying in diameter between $\frac{3}{16}$ in. and 1⅛ in. The mixture of the concrete was 1–2–4. The execution of the reinforced concrete work was carried out by Messrs. Pulham & Son, under the supervision of Messrs. Edmond Coignet, Ltd.

To the Turner Construction Company, who were the contractors for the structures, we are indebted for the photographs of the Army Supply Base at Brooklyn; Factory and Warehouse at Brooklyn; Printing Works in New York City; Factory building at Long Island City; and Washington Mills.

Other American illustrations, as follows, were kindly supplied by the American Portland Cement Association: Spanish type bungalow in California; Fountain of Time, Chicago; Twenty-two story building at Dayton; Medical Arts Building, Dallas; Reproduction of the Parthenon at Nashville; Concrete house in Florida; Monument to an American Indian.

The cast-stone dressings on the cinema at Ilkeston are the work of the Trent Concrete Co., Ltd., of Colwick, Nottingham.

Messrs. Evans Bros. (Concrete), Ltd., were responsible for the dome at Ilkeston.

Mr. B. J. Wormleighton, Surveyor to the Herne Bay Urban District Council, is responsible for the concrete work on the front at that town. The pavilion, entirely of reinforced concrete, is 75 ft. 6 in. long by 40 ft. wide by 18 ft. high, and comprises a shelter on the sea front and a ladies' convenience on the road side. The whole of the faced work is in pre-cast concrete, made of ground Portland stone and cement, about 1½ in. thick. These castings were hoisted and fixed in position to form the shuttering for the reinforced concrete work carrying the loads. The roofs are flat, and made of concrete reinforced with wire mesh. With the exception of the mouldings around the door and window openings, all the moulded work is in pre-cast concrete built in as the work proceeded. The floor is in pre-cast concrete flags with Kent ragstone as aggregate, laid diagonally within a border of granite-faced *in situ* concrete. The dwarf wall illustrated has been carried out as part of the same work of reconstruction along the sea front. A notable feature of this work was the use of an ordinary standard outfit of straight-wall "Metaforms" for the whole of the concrete work, the formation of the pedestals, sunk panels, and flower vases being obtained by the insertion of shaped pieces of wood to the inside of the forms. Nothing has been done to the surface after it left the forms, as the metal left a surface sufficiently perfect.

The band enclosure at Southport occupies an area of 3,690 sq. ft., and is surrounded by cast-stone balustrades about 3 ft. 9 in. high; there are about 1,000 lineal feet of this balustrading, such as that shown in our illustration. The two flank entrances are of an imposing character, having groups of Ionic columns on each side surmounted by architrave, frieze, and cornice, all being in cast stone to match Portland stone.

The Cappelon Memorial Bridge at Minneapolis has the longest span (400 ft.) in America, and our illustration is given by courtesy of the City Engineer.

Tunkhannock Viaduct, Pennsylvania, is claimed to be the longest structure of its kind in the world. We are indebted for our photograph to the Delaware, Lackawanna & Western Railroad Company, on whose line it has been built.

The Detroit Towers Apartment House was designed so far as the reinforced concrete work goes by the Gabriel Steel Company, and the Fairmont Memorial Bridge by the Concrete Steel Engineering Company; and to these companies we owe our photographs.

Tonneins Bridge, France, was built by the famous contracting firm of Limousin, who have lent us the illustration.

Prospective New Concrete Work.

Aylesbury.—*Houses.* — The R.D.C. proposes to erect 100 houses.

Barwell.—*Houses.* — The Hinckley R.D.C. proposes to erect 50 houses.

Bexley (Kent).—*Footbridge.*—A footbridge is to be constructed at Bexley Bridge.

Blyth.—*Reservoir.*—The T.C. is negotiating for the purchase of a site for a reservoir.

Bolton.—*Houses.*—The B.E. is negotiating for a site for housing purposes.

Bradford.—*Road.*—The Corporation proposes to construct a by-pass road to Wyke, at a cost of £50,000.

Brierley Hill. — *Houses.*—Application has been made for a loan of £42,530 for housing purposes.

Buckfastleigh. — The U.D.C. proposes to replace the brick pavement in Fore Street with concrete.

Bulkington.—*Houses.*—The U.D.C. has applied for permission to erect 20 houses.

Chepstow.—*Bridge.*—The U.D.C. is considering a scheme for the construction of a bridge over the Severn at Beachley.

Coventry.—*Roads.*—The City Council proposes to spend £318,000 on the construction of roads.

Cudworth. — *Houses.* — The U.D.C. proposes to erect 40 houses.

Derby.—*Reservoir.*—The T.C. has purchased land at Drumhill, Breadsall, as a site for a reservoir.

Doncaster.—*Houses.* — The Corporation is considering the question of erecting 136 houses on the Woodfield Lane site.

Douglas, I.O.M.—*Breakwater.*—A proposal is being considered for the construction of 900 ft. of breakwater. The cost is estimated at £750,000.

Dumfries.—*Concrete Houses.* — The T.C. proposes to build 100 concrete houses.

Durham.—*Road.*—The Durham C.C. proposes to construct roads from Chester Dene to Jingling Gate, from Jingling Gate to Hylton, and from Hylton Bridge to Seaham.

Edinburgh.—*Concrete Houses.* — The Corporation proposes to build 125 concrete houses at a cost of £480 each.

Epsom.—*Houses.*—The U.D.C. proposes to build 30 houses.

Felinissa. — *Bridge.* — The St. Dogmaels R.D.C. proposes to erect a bridge at Felinissa.

Frinton.—*Groynes.*—The U.D.C. has instructed the Surveyor to prepare plans for replacing the timber groynes on the beach.

Glasgow. — *Concrete Houses.* — The Housing Committee recommends the Corporation to build 500 concrete houses at Langlands.

Gloucester. — *Houses.* — The C.C. has applied for a loan of £31,500 for housing purposes.

Great Ouseburn.—*Houses.* — The R.D.C. has applied for permission to erect 500 houses during the next five years.

Great Yarmouth.—*Concrete Road.*—The T.C. proposes to spend £4,575 on the reconstruction of Southgates Road in reinforced concrete.

Great Yarmouth.—*Groyne.* — The Corporation proposes to spend £380 on the construction of a groyne.

Greenock.—*Road.*—A scheme is being considered for constructing a 60-ft. wide road from Gray Place to Rue End.

Hastings.—A scheme is being considered for the construction of concrete bathing cabins.

Hull.—*Road.*—A road is to be constructed from Southcotes Lane to the East Hull housing site.

Keighley.—*Houses.* — The Corporation has applied for a loan of £37,000 for housing purposes.

Lagganmore. — *Bridge.* — The Lorn District Committee of the Argyllshire C.C. proposes to erect a bridge at Lagganmore on the Kilninver Road.

Lanark.—*Houses.*—The Lanarkshire C.C. has applied for permission to borrow £720,000 for the construction of 1,600 houses in various areas of the district.

Leeds.—*Houses.* — The Corporation has applied for a loan of £433,538 for the construction of 851 houses.

Loughborough.—*Concrete Bridge.*—At a cost of £1,050 the Council proposes to erect a reinforced concrete bridge at Bridge Street.

Luton.—*Houses.*—The T.C. has applied for a grant for the construction of 200 houses.

Maidstone.—*Houses.*—The Corporation has applied for a loan for the erection of 47 houses in Upper Faut Road.

Mansfield.—*Houses.*—The T.C. has applied for a loan of £51,500 for the construction of 108 houses on the Bull Farm estate.

Northfleet, Kent.—*Concrete Houses.*—The U.D.C. proposes to erect 70 concrete houses by direct labour. The estimated cost is £500 each.

Old Windsor.—*Road.*—The Berkshire C.C. is seeking permission to construct a by-pass road at Old Windsor.

Paisley.—*Road.* — The Corporation proposes to construct a 100-ft. wide road from the Cross to New Smithhills.

Pontardulais.—*Road.*—The Swansea R.D.C. is negotiating with various public authorities concerned for the construction of a road from Pontardulais to Pantyffynon. The cost is estimated at £90,000.

Portscatho.—*Breakwater.* — A Committee has been appointed to discuss the question of erecting a breakwater at Portscatho.

Portsmouth.—*Houses.*—The Corporation has applied for permission to erect 300 houses.

Rochford.—*Concrete Bridge.* — Plans have been received for the construction of a reinforced concrete bridge to connect Canvey with Benfleet.

Seaham.—*Houses.* — Application has been made for a loan of £22,000 for the erection of 56 houses.

Sneinton.—*Houses.*—The Nottingham Corporation proposes to purchase 38 acres for a housing site.

Southwold.—*Sea Defence Works.*—The T.C. is considering a scheme for the protection of the sea front.

Sunderland.—*Houses.*—The Corporation has applied for a loan of £62,008 for the construction of 136 houses.

Sunderland.—*Retaining Wall.*—The Corporation has applied for a loan of £18,000 for the construction of a retaining wall.

Swinton.—*Houses.*—The U.D.C. has applied for permission to borrow £31,500 for the erection of 70 houses on the Cliffe Field.

Weetslade.—*Houses.* — The U.D.C. has applied for permission to erect 50 houses at Dudley.

Weetwood.—*Bridge.*—The Leeds Corporation proposes to erect a bridge at Smithy Mills Lane, Weetwood.

Weymouth.—*Houses.*—The T.C. is negotiating for the purchase of a housing site for the construction of 200 houses.

Whitby.—*Bridge.*—The U.D.C. proposes to erect a bridge to connect East Cliff and East Pier.

Winchester.—*Houses.*—The T.C. proposes to build 42 houses.

Wolverhampton.—*Bridge.*—The Corporation proposes to spend £41,740 on the construction of a road and bridge.

Wrexham.—*Bridge.*—The Council is considering a proposal to erect a bridge over the River Gwenfro, from Bridge Street to Tuttle Street.

Tenders Accepted.

Bognor.—The U.D.C. has accepted the tender of Mr. H. N. Seymour, Bognor, at £2,450 5*s.* 10*d.*, for the construction of 3,000 sq. yds. of concrete carriageway. Other tenders submitted were: A. Watson, Ltd., £2,664; Morrisons (Roads), Ltd., £2,854; Walker-Weston Co., £3,278; R. H. Hartley & Co., £3,470; Mears Bros., £4,396.

Carlett.—*Concrete Road.*—The Cheshire C.C. has accepted the tender of Mr. C. L. Warren, Seacombe, at £6,590, for the construction of a reinforced concrete road.

Dodworth. — *Sewage Works.* — The U.D.C. has accepted the tender of Messrs. J. Bentley & Co., Bradford, at £6,900, for the construction of sewage disposal works at Dodworth.

Leicester. — *Concrete Houses.* — The T.C. has accepted the tender of Messrs. Henry Boots & Sons (London), Ltd., for the construction of 500 concrete houses.

Maidenhead. — *Concrete Sheds.*—The T.C. has accepted the tender of Messrs. Cripps & Green for the construction of concrete sheds.

Port Talbot.—*Concrete Piling.*—The T.C. has accepted the tender of Messrs. K. Holst & Co., at £1,670, for pile-driving and reinforced concrete foundations to a gas-holder at the Aberavon Gas Works. Other tenders submitted: Industrial Constructions, Ltd., £1,860; Peter Lind & Co., £1,990; Christiani & Neilsen, £2,050; A. Scott, £2,440; Simplex Concrete Piles, Ltd., £2,500; Yorkshire Hennebique Contracting Co., Ltd., £2,650; Gray's Ferro-Concrete Co., £2,694; Mackenna, Ltd., £2,990.

Portsmouth. — *Concrete Balustrade.*—The T.C. has accepted the tender of Mr. J. Croad, Portsmouth, at £975, for the construction of a concrete balustrade in Clarence Parade. Other tenders submitted were: Marchetti, Ltd., £1,081; C. J. Gutteridge, £1,120 10s.; F. Bevis, Ltd., £1,150.

WILLESDEN (LONDON). — *Concrete Houses.*—The U.D.C. has accepted the tender of the Corolite Construction Co. for the erection of 100 concrete houses.

WORTHING.—*Reservoirs.*—The T.C. has accepted the tender of Messrs. Playfair & Toole, Ltd., at £8,543, for the construction of reinforced concrete reservoirs at Durrington and High Salvington.

Trade Notices.

Peter Lind & Co.—An excellent idea of the volume and wide variety of reinforced concrete structures designed and executed by Messrs. Peter Lind & Co. (2, Central Buildings, Westminster, S.W.1) during the ten years the firm has been in existence may be gathered from the new catalogue they have just issued. The firm specialises in industrial works in reinforced concrete, and in the new catalogue are illustrated a profusion of such structures as machine shops, warehouses, stables, workshops and factories, gantries, piling, foundations, engine pits, grain silos, gasworks structures, coal bunkers, gasholder foundations, screening plants, conveyors, tanks, power houses, transformer houses, foundations for turbo-alternators, cooling-tower foundations, winding-engine houses at collieries, pit linings, reservoirs, water towers and tanks, etc. For convenience of reference the catalogue is divided into sections dealing with Industrial Buildings, Foundations, Piling, etc.; Gasworks; Electric Power Stations; Collieries; and Bridges and Culverts. The last section includes such artistic structures as the bridges over the rivers Aire and Ouse, in which the designers have shown how attractive a reinforced concrete bridge can be made to appear. The sections devoted to gasworks and electric power stations show what a large number of such structures the firm has been responsible for, and include the big stove and meter works now under construction at Fulham for the Gas Light & Coke Company. The catalogue is an attractive production printed on good paper, the illustrations being particularly well-produced; as a rule a photograph and section is given of each structure, and these are given to a scale which makes them of real value.

Grabs.—One of the most notable developments in the improvement of mechanical plant for the contractor has been the introduction of machinery for excavation work. Steam navvies are being used to an increasing extent nowadays, but there are still a large number of works on which they could be used more economically than hand labour. Cement makers and similar industries involving a large amount of excavation carry out this class of work practically entirely by mechanical means, as also do contractors on large contracts. In the United States the saving which may be effected by mechanical diggers is realised to such an extent that in practically every town of any size at all at least one contractor possesses one, which he hires out to others when it is not required for his own work. With the increasing use of this type of plant, the manufacturers are continually improving their products. The new type of grab illustrated herewith is manufactured by Messrs. William Goodacre & Sons, Ltd., of Russell Road, Victoria Dock, E.16, and is shown in operation excavating heavy London clay. It is specially designed for heavy work, and deserves the attention of firms making use of such plant.

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FEBRUARY 1926 CONCRETE SERIES No1 VOL. XXI No. 2

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Control of Reinforced Concrete Construction.

DRASTIC recommendations for the control of reinforced concrete construction have been made by a board appointed by the Victorian Ministry following the collapse of a building which was being constructed in the centre of Melbourne. This Board has recommended the appointment of a permanent board of experts whose duty it would be to examine for registration concrete designers, constructors and supervisors.

The report states: " Should any person desire to be registered or licensed he should be able to prove to the satisfaction of the board his competency to perform the work in question in any way that the board might think fit, and the board should be free to exercise its discretion without restraints being placed upon its determinations. The board should not be hampered by opening the door wide enough to admit all and sundry to the initiation of the work. If the door be opened to anybody who claims to have done work in reinforced concrete the granting of a certificate might lead to disaster. The board should make regulations relating to any reinforced concrete structure. The regulations should prescribe methods of preparation of plans, computations and specifications, methods of construction, materials to be used and their preparation, methods of workmanship, supervision and construction, the fixing of responsibility, the fixing of standard specifications and tests, and prescribing for their adoption, penalties for the contravention of any regulation, and generally to make regulations regarding such other matters as might, in the board's opinion, be necessary for the proper construction of reinforced concrete structures. Any accident arising out of the design or construction should be *prima facie* evidence that such accident occurred through negligence on the part of the designer, and any accident arising out of the supervision should be *prima facie* evidence that such accident occurred through negligence on the part of the supervisor."

The board suggests the registration fee for designers and constructors should be £4 4s. and for supervisors £1 1s., and adds: " Penalties not exceeding £20 should be provided for offences against the regulations, with a further sum not exceeding £2 for each day the offence is continued after written notice has been given by the surveyor of the district in which the construction is being carried out." The board also suggests that the Commonwealth Parliament should take similar action so that concrete construction would be specially regulated throughout Australia.

At great expense, and after many years of effort, the medical, dental, nursing, and other professions have obtained statutory registration in Great Britain, and architects are now more or less united in their desire to secure registration. In Australia, apparently, reinforced concrete designers are having statutory registration thrust upon them, and providing the object is a genuine wish to protect the public from the unqualified engineer, and that this can be done without putting in force hampering regulations, we wish all success to the movement.

Cold Weather Concreting.

AUTHORITATIVE reports are now available on the collapse of a reinforced concrete hotel building at Benton Harbour, Michigan, during construction in January last year, and emphasise the necessity for adequately protecting newly poured concrete during cold weather. The building in question covered an area of 100 feet by 100 feet, and had reached the eighth story when the collapse occurred. It was commenced in November, 1924, so that it was intended to be built practically entirely during a period of low temperature. It has been proved that the design of the building was thoroughly sound, as also were all the materials used. Precautions were taken to warm the concrete before it was poured and to protect it until it had set, but these proved to be insufficient, and, according to the reports, were the sole reason for the collapse. We gather that the provision of an increase of about 25 per cent. in the number of fire buckets used, and the retention of the tarpaulins covering the work for a day or two longer, would have prevented the enormous loss which the failure of this large building must represent. The temperature at Benton Harbour when the accident occurred was continuously below 30 deg. Fahr., and often below zero, and although we do not get such severe conditions in this country, this collapse does point out the need for taking every precaution in covering up and keeping the material warm, not only when the temperature is actually freezing but whenever there is a possibility of a cold snap occurring.

Houses, Materials, and Labour.

WE are all aware of the acute shortage of houses. We know the overcrowding that exists ; we have read about the long waiting lists for houses on municipal estates ; we realise the discontent existing because of this state of affairs. We desire to see houses built fast enough to remedy this evil in the shortest possible time, and have watched the attempts of successive Governments with considerable interest. We are particularly interested in the latest move of the present Government in advocating steel houses, and not only advocating them but actually building houses of this material in Scotland through the agency of the Scottish National Housing Company. The steel house has been adopted on the ground that there are not sufficient labour or materials to build sufficient houses by any other method. If this were true it would probably be sound policy to build huts of corrugated iron to tide over the period until something more substantial could be put up. We must have a dwelling of some kind, and anything is better than nothing. But—and this is the essential point—is it impossible to build houses in large numbers without causing such an upheaval and dislocation in ordinary house building as is threatened by the steel house? We think it is.

In spite of the rhetoric of those who claim to speak on their behalf, we do not think the public wants a steel house if it is at all possible to have one built of a material with which they are more familiar. Certainly the local authorities are fighting shy of them, as is proved by the fact that all the flourishing of trumpets during the past year or more has only resulted in the erection of about a couple of hundred. The building trade unions, for reasons with which we do not agree but which nevertheless exist and have to be contended with, are opposed to them, and threaten to stop work on other houses in districts where any attempt is made to build in steel. Builders do not like them, perhaps for very much the same reasons as the operatives. The cost of the steel house is no less, and in some cases actually more, than the cost of a brick house.

Obviously no Government would build in steel in face of all these difficulties unless it were convinced that there was no alternative, and one can only wonder why the concrete house has not received more attention. We say " wonder " because the Government must know the progress that has been made in concrete house construction. Their own figures show that nearly 25,000 concrete houses were built last year, and that certain contractors have organised their businesses to erect them by the thousand at a speed which will compare favourably with anything that is claimed for steel. There can be no difficulty on the score of materials, as suitable aggregates are found in abundance in most localities. Concrete houses make no call on labour that could be employed on other methods of building; there are hundreds of thousands of unskilled workers on the books of the Employment Exchanges who, with a brief training and proper supervision, could be usefully employed on concrete house construction. The difficulties with the trade unions on the question of the employment of unskilled labour on concrete houses were fought out and settled years ago, and 25,000 houses were built last year without labour troubles. Concrete houses exist all over the country; people have become accustomed to see them and to live in them.

Why, then, is the steel house officially sponsored and boosted? To the man in the street it seems more than folly to stir up discord in an industry which is now producing houses at the unprecedented rate of 200,000 a year, and risk checking this output for the sake of a mistaken view that steel is the only alternative to brick which does not encroach on existing materials and labour.

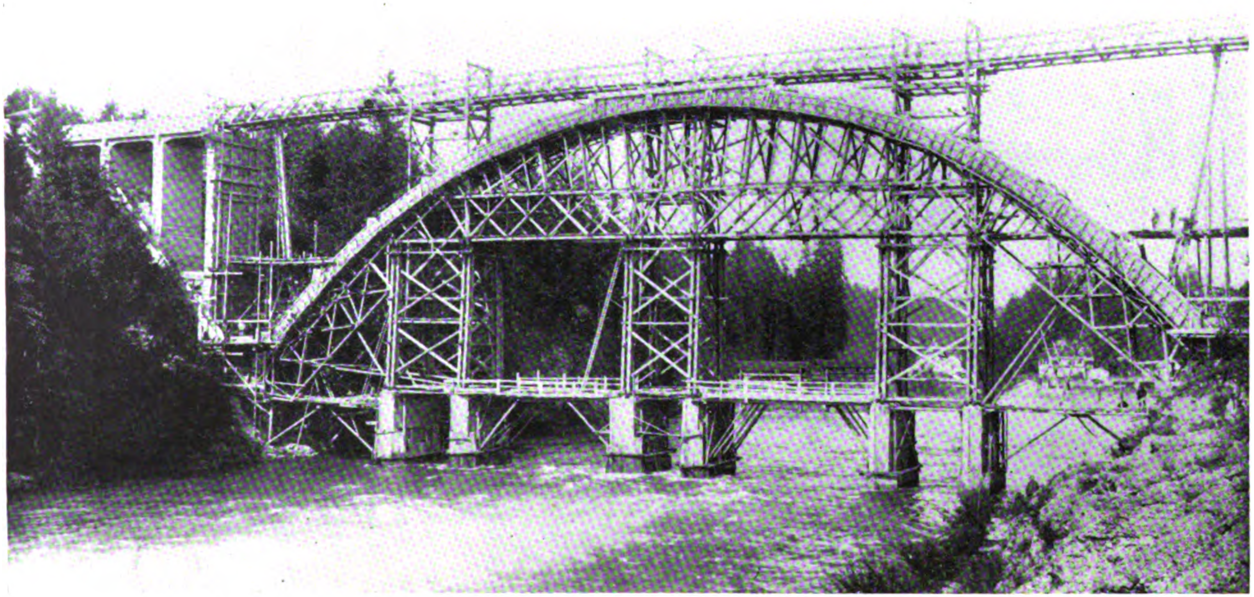


Fig. 1.—Traunfall Bridge, Austria, during Construction. (*See p.* 171.)

Tests on Hooped Cast-Iron Concrete.

By R. N. STROYER, M.I.Mech.E.

In connection with the building of a reinforced concrete bridge of 215-ft. span, in which the compressive reinforcement consisted of cast-iron, some interesting tests on compression members of this description were carried out recently, and as they showed conclusively the superiority of hooped cast-iron as compressive reinforcement, a description of the tests may be useful.

This system of reinforcement was invented by Dr. Emperger and has been used extensively on the Continent and in America, not only for constructional members subject to compression only, such as columns in heavy warehouses, but also in members subject to combined bending and compression, a whole series of arch bridges testifying to the correctness of the assumptions and calculations used in connection with this combination of materials.

The bridge in question (the Traunfall bridge) replaces an old timber bridge over a rocky valley near Gmunden, in Upper Austria, and is designed with two arch ribs of the two-hinge variety, carrying the roadway by a system of columns supporting the deck beams and slab (*Fig.* 2). The cost of the proposed scheme was so much below that of the ordinary reinforced concrete schemes that it was chosen by the local authorities subject to satisfactory tests being carried out on members identical with those actually embodied in the construction of the arches. A paragraph in the local regulations for reinforced concrete provides for tests under actual working conditions of any part of a structure the design of which does not come within the limits of the regulations, the actual factor of safety required being 3, or, rather, the test load required being 3 times the working load for which the member in question is designed. The statical calculations gave the forces acting upon the quarter-point section as shown in *Fig.* 4, and in order to be able to test to destruction without having to deal with forces of exceptional magnitude it was decided to reproduce a half-size section, i.e. with a linear 1:2 reduction and a 1:4 reduction of areas and forces; the worst case in *Fig.* 4, with 296 tons acting at a distance of 40 cm. from the centre, therefore corresponds to 74 tons at 20 cm. in the test body.

Tests on eccentrically-loaded compression members in ordinary reinforced concrete have not been carried out in great numbers, and more particularly is there a scarcity of tests with an eccentricity exceeding the middle third, i.e. cases where both tension and compression obtain in the section. Still fewer, if any, tests have been made on hooped concrete subject to combined bending and compression, and there is no actual proof that an increase of the compression strength of concrete in flexure is obtained by hooping, and consequently some regulations for reinforced concrete do not take it into account at all. The object of the hooping of the concrete surrounding the cast-iron reinforcement is partly

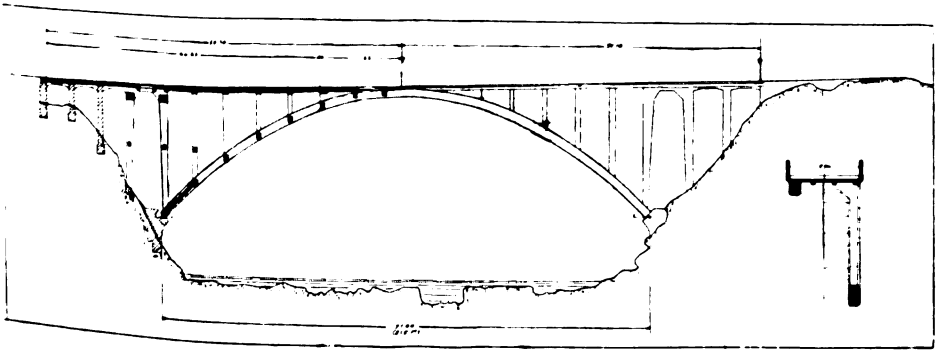


Fig. 2.

Fig. 1.—Traunfall Bridge, Austria, during Construction. (See p. 171.)

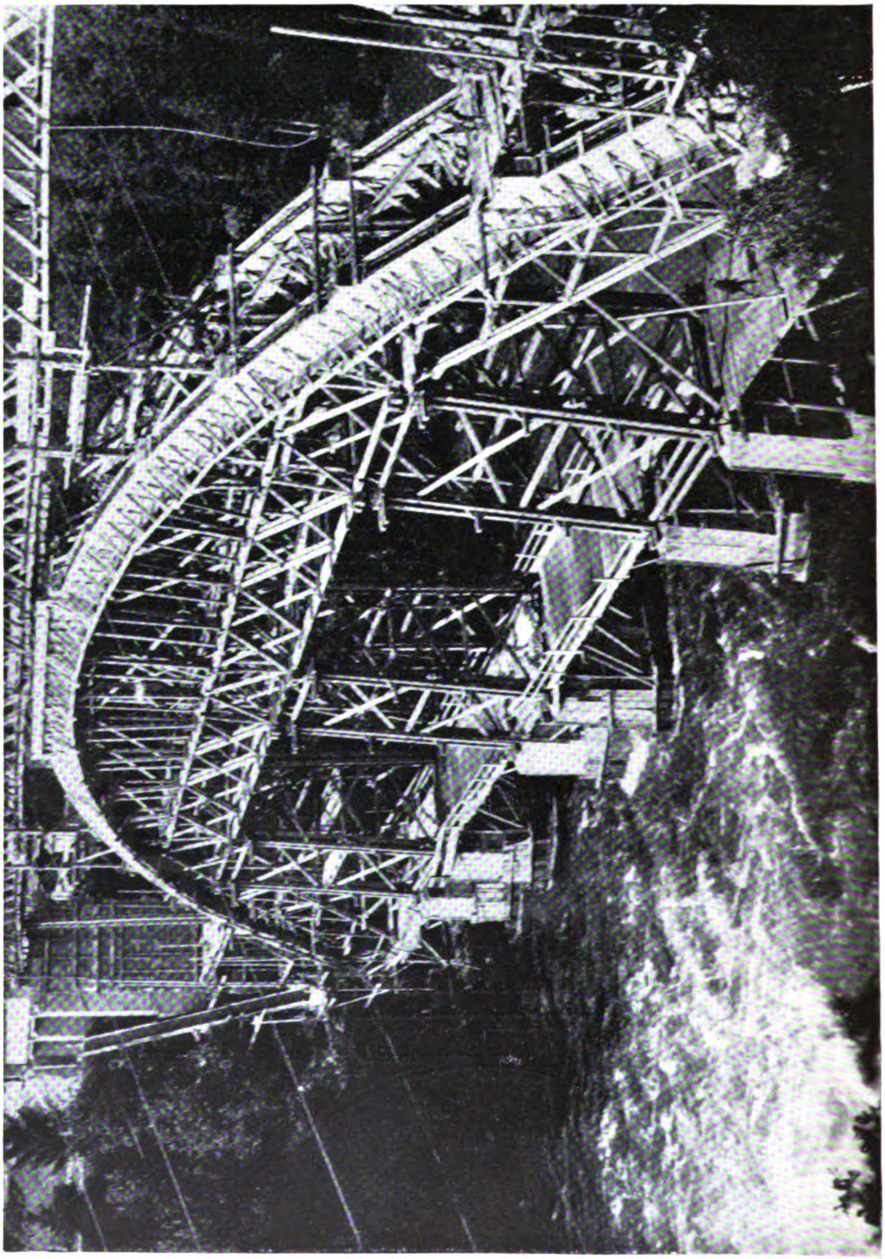


Fig. 3.—Traunfall Bridge, Austria, during Construction.

to reduce the brittleness of the iron and partly to increase the compression strength of the concrete, to such an extent only that the two elements (the cast-iron and the concrete) shall act together in the way shown by Dr. Emperger's numerous tests. The test-piece is shown in detail in *Fig.* 5, from which it will be seen that the unsupported length is about 4 ft. 6 in., and that a butt joint in the cast-iron reinforcement is introduced in the middle, so that no tension may be taken by it.

During the tests it was found that not only did the presence of the cast-iron increase the compressive strength of the section, but it also delayed the appearance of the first tension cracks to a considerable extent; under the eccentric action of the cast-iron the neutral axis moves in the direction of the eccentricity and thereby decreases the tension stresses, so that at the breaking load only a few small cracks appeared. The first test took place eight days after concreting, when the concrete had attained a crushing strength (cube) of 1,840 lbs. per sq. in. and a corresponding tensile strength of 184 lbs. per sq. in. In these circumstances an ordinary reinforced concrete test-beam would have reached its breaking load at 104 tons, but the test was carried on until the first hair crack appeared at 226 tons, the test-piece being otherwise perfectly sound. After being left in the machine until the concrete was four weeks old and had attained a crushing strength of 3,600 lbs. per sq. in., the test was continued until the hooping burst, at 440 tons. This bursting was very clearly observed, and a little while after the crushing of the cast-iron took place

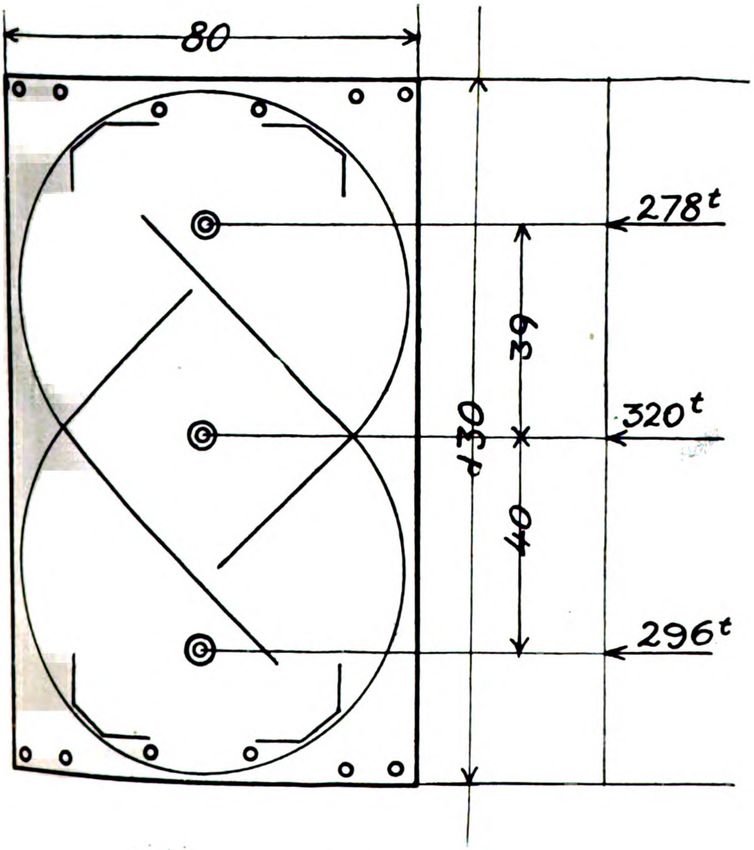


Fig. 4.

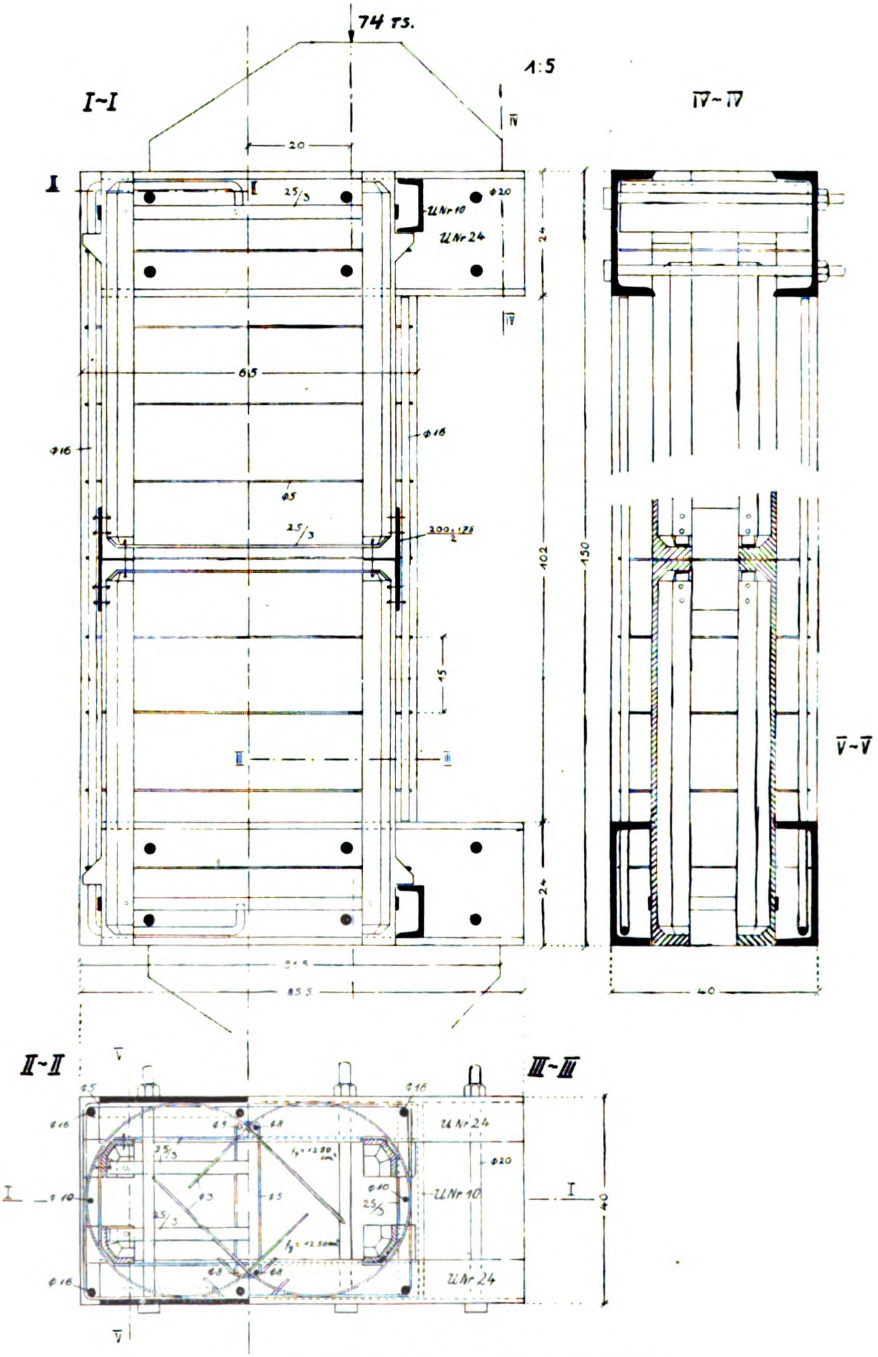


Fig. 5.—Traunfall Bridge, Austria.

at the point where the hooping had given way. The condition of the test-piece at this stage is shown in *Fig.* 6.

The amount of hooping in this case was fairly low, being only about 0·3 per cent., and was not sufficient to allow the cast-iron to develop its full strength, and in order to show that an increase in the volume of hooping would result in an increased utilisation of the cast-iron, another test-piece was prepared identical with the previous one in all respects save that the hooping had been increased to 0·45 per cent. In this test the first hair crack appeared at 300 tons, and crushing took place at 500 tons under similar conditions as in the previous test.

The two tests showed a considerably

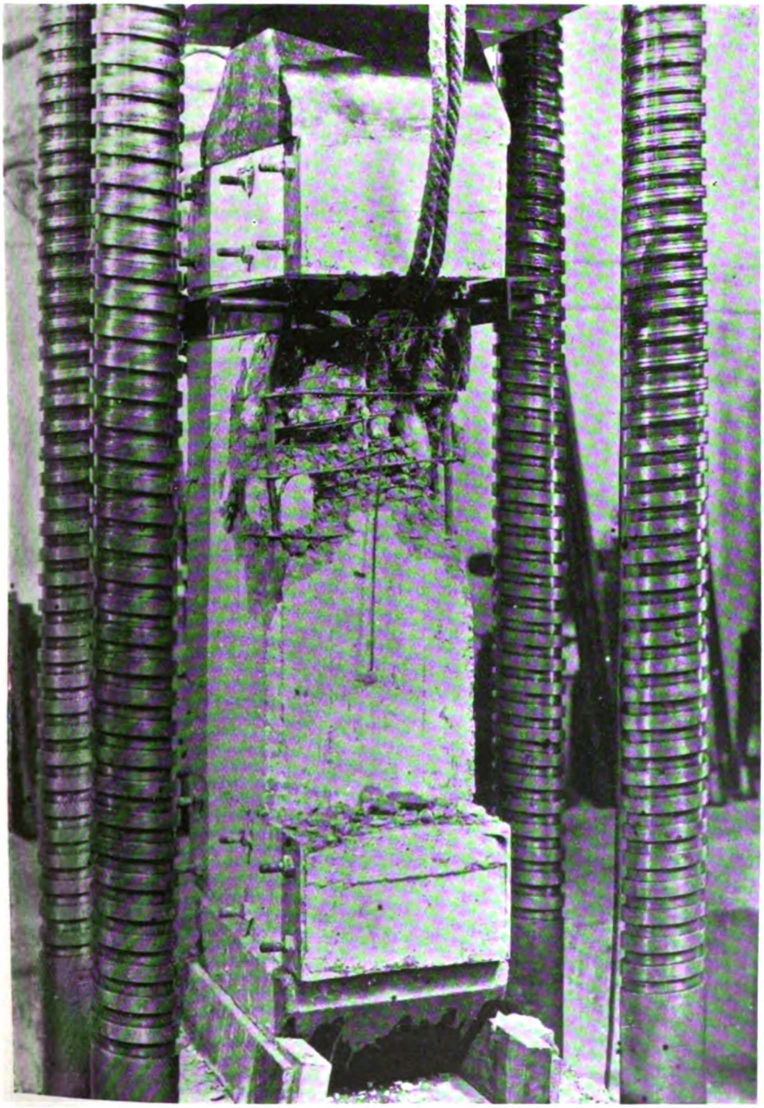


Fig. 6.

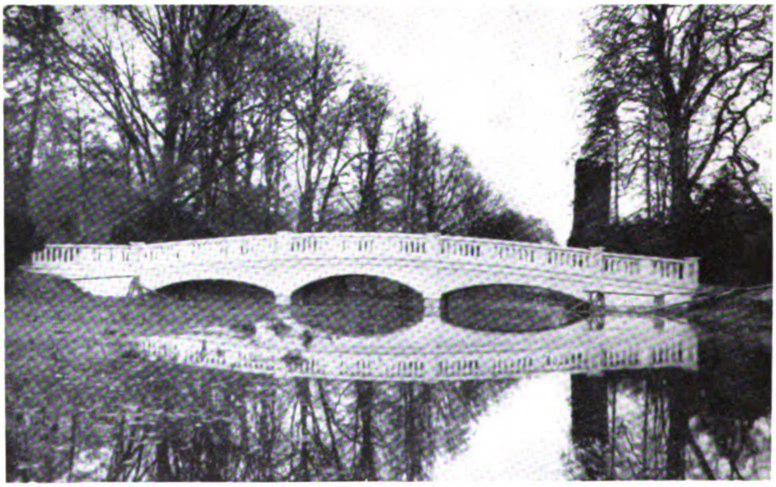
higher factor of safety than required, and also that a further increase of hooping might have increased the crushing strength, as in both cases the cast-iron crushed at a lower stress than separate direct crushing tests on the cast-iron.

An important fact elucidated by the tests was the relation between the stress in the cast-iron and in the concrete; the value of this ratio, which in a number of previous compression tests had been found to be in the neighbourhood of 40, was confirmed by the new tests, and this figure serves to bear out the very high utilisation of the cast-iron reinforcement in comparison with mild steel.

The comparative strength of a concrete section reinforced with hooped cast-iron and one with steel bars only is approximately as 2 to 1, or practically in the same proportion as reinforced concrete to plain concrete; so that, in other words, a column of given dimensions which would carry 20 tons if in plain concrete would carry about 40 tons in reinforced concrete and about 80 tons in hooped cast-iron. This is of importance where heavy loads are encountered, and for this reason hooped cast-iron has been used lately to a great extent in American skyscrapers, but the same considerations apply equally well to other compression members. The Traunfall bridge might have been built in ordinary reinforced concrete and presented the same side elevation, but the number of arch ribs required would have been four instead of two.

Concrete Bridge at Thetford.

THIS bridge is constructed in reinforced concrete throughout, and spans the Little Ouse at Euston Hall, Thetford; it is a private bridge forming the approach to the Hall, the seat of the Duke of Grafton. Mr. George Kenworthy, A.M.Inst.C.E., was the consulting and designing engineer, and the contractors were Messrs. Christiani & Nielsen.



Concrete Bridge at Thetford.

With its wing approaches, the structure is practically 115 ft. long, and it may be mentioned that the foundations gave a considerable amount of trouble as the river bed was found to consist of running sand, and piling had to be resorted to. Reinforced concrete piles made with rapid-hardening Portland cement were used for the purpose. The arched ribs and the parapet are all covered with, or made solid in, "Atlas White" cement. Expansion joints are provided over each abutment so as to be entirely hidden from external view. This new bridge replaces an oak structure about sixty years old.

Combined Bending and Direct Force.

By DR. NICHOLAS KAMM.

WE have received the following notes on Mr. Chas. E. Reynolds' article in our issue for December, 1925, from Dr. Nicholas Kamm (Director of Messrs. Engine Foundation and Concrete Contractors, Ltd.) :—

Mr. Chas. E. Reynolds, B.Sc., published in the issue of this journal for December, 1925, a comparatively simple method of determining the section and reinforcement required and the stresses produced in given sections of reinforced concrete members subjected to a direct force acting outside the core of the effective surface and thus producing tensile and compressive stresses. In view of the extraordinary importance of the subject, I hope I may be permitted to offer a critical appreciation of Mr. Reynolds' statements.

The new idea on which Mr. Reynolds' method is based consists in assuming an axis which bisects the vertical distance between the resultants of compression and tension stresses. Now, in the course of his demonstrations the author assumes that the bending moment and the direct force are known ; the direct force acts about the assumed bisecting axis, and the moment is also taken as acting about the same axis. For the other case in which the actual line of action of the force is known, he states that for the further calculation it is necessary first of all to find the distance between the line of action of the direct force and the bisecting axis mentioned above.

First let us deal briefly with these bases of calculation.

In reinforced concrete structures subjected to bending and axial forces it is usually a question of statically indeterminate supporting structures. Most frequently they are frames, arches, and vaults in which bending and eccentric compression mainly arise. Less frequently we find it in silo and tank walls, in the tie members of arched bridges, etc., where we get bending with axial tension. In order to determine the moments and direct forces in such structures we have first to assume the form of sections. It is then usual to take the axis of gravity of the concrete section as the system axis. It is not possible at first to take the axis of gravity of the actual effective section surface together with the concrete tension zone as the system axis ; at first we do not know the effective surface, besides which we should get a different position of the axis for each section and for each of the various ways of loading to be examined.

The method whereby the calculation is based on the full concrete section is quite in accordance with the object of the calculation (i.e. to determine the action of external forces on the elastic system), for under the stresses expected the tension concrete will also take its part. Only in the second part of the calculation, where the safety of individual parts against rupture is concerned, must we assume that the tensile stresses in the concrete have exceeded the permissible limit and that the tension member has thus become ineffective. On the other hand, however, in indeterminate problems it is first of all a question of knowing the ratio of the moments of inertia, and it would serve no purpose to demand too great a degree of accuracy in the preliminary calculations. A revised calculation of the structure in determining the moments of inertia will always have due regard to the reinforcement obtained from the first calculation, and will measure the action of forces about a mean axis of gravity with due regard to the reinforcement.

In calculating the external moments on which the reinforcement is based, it will be found that generally in individual cases these are only quite accurate when the assumed system axis accidentally coincides with the axis of gravity of the actual effective section. The inaccuracy otherwise resulting will be all the greater the larger the distance between the selected system axis and the axis of gravity. On the other hand, the discrepancy will be the smaller the farther away the direct force is applied from the axis of gravity and the system axis ; that is to say, the greater the action of the moment opposed to the direct force. The system axis selected passing through the centre of gravity of the concrete, and the axis proposed by Mr. Reynolds, generally deviate to a relatively slight extent from the axis of gravity.

The results of both methods will, therefore, generally suffice in practice, and will gain in accuracy with increasing moments. In general, any refinement of these principles would be out of place because the suppositions made as to the constancy of the expansion masses do not prove correct in actual practice. But whilst the choice of the centre line of the concrete section as the system axis appears to be indicated by the course of calculation of the external forces, and generally it will only be found necessary to deviate from this method for subsequent calculations in cases where the action of the direct forces is very considerable, still it will invariably only be possible to introduce the system axis proposed by Mr. Reynolds at a later stage.

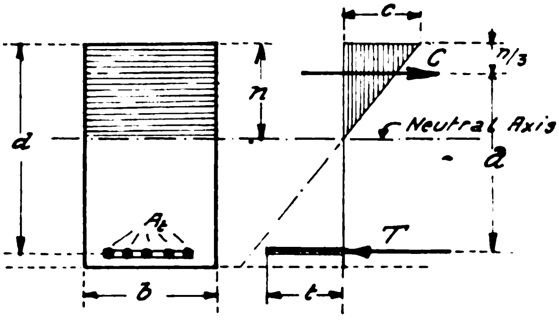
Assuming that the position and value of the external force are known, it remains to be investigated whether the method proposed by Mr. Reynolds really presents the advantage of considerably greater simplicity than the methods used hitherto. The answer would be that for the most part this is not so. The ultimate object of all methods of calculation is to establish conditions of equilibrium between the external and internal forces.

In principle it is immaterial what axis or points are taken as a basis for the moments. At the most there may be a certain degree of simplification when, for instance, the usually simple summation equation of the normal forces, which is generally used as a check, is employed in place of a momental equation, or in that the algebraical terms are simpler to set down.

After these explanations of the principles of calculation, let us review each of Mr. Reynolds' demonstrations.

Bending and Tension.

Case 1.—The solution is the same as in the older methods, which is given, for instance, by Mörsch in his text-book, "Reinforced Concrete," 5th edition, Volume I. The influence of the other reference axis may be said not to appear at all in this case, for using Mr. Reynolds' symbols we readily obtain with Mörsch's formulæ



$$n = \frac{m.c.}{m.c+t} \cdot d;\quad a = d - \frac{n}{3},\quad b = \frac{2M_t}{c.n.a} = \frac{2C}{c\,n.}$$

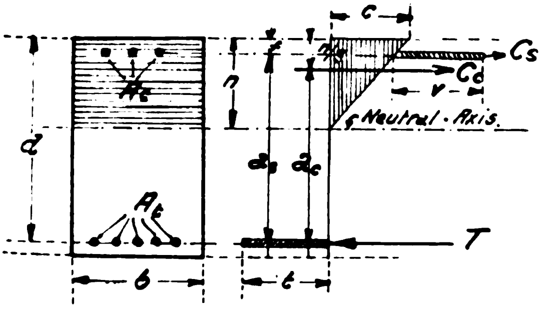
$$\text{resp.: } C = \frac{n.b.c}{2};\quad A_t = \frac{C+N}{t}.$$

Case 2.—In calculating the stresses on a given section it is really not possible to simplify the work. Even Mr. Reynolds cannot, of course, avoid determining the position of the neutral axis. But as this can be done analytically only by solving a cubic equation he prefers to assume it, then to calculate the stresses, and then to check the assumed value backwards, if necessary repeating the calculation with a revised value of *n*. It would, however, be better to establish the cubic equation for *n*, as usual, with the help of Cardan's formula from the reduced cubic equation and then to determine the final stresses with the correct value of *n*. It is true that the neutral axis and the stresses may frequently be found more quickly by the graphic method. Finally, in practice one is generally content to know, even in checking calculations, that the permissible stresses will not be exceeded.

For this reason one might take the simpler reverse method (Case 1) and ascertain whether the reinforcement required for the permissible stresses agrees with the reinforcement actually provided. Assuming the position of the neutral axis to be known, by using Mr. Reynolds' symbols, we obtain quite as briefly:

$$c = \frac{2M_t}{b.n.a} = \frac{2.C}{b.n} \qquad t = \frac{C + N}{A_t}.$$

(See Saliger, "Reinforced Concrete," 4th edition, page 250–9*a*.)



$$M_t = A_c . v[d-f] - c.\frac{b.n}{2}\left[\frac{n}{3}-f\right]$$

$$M_c - A_t . t[d-f] + c.\frac{b.n}{2}\underbrace{\left[d-\frac{n}{3}\right]}_{a}$$

Case 3.—For designing a section with steel on both faces, where the stresses are not to exceed given values of *c* and *t*, the method given in Mörsch (Vol. I, page 437) should be clearer. As in Mr. Reynolds' method the position of the neutral axis is found from the given values *c* and *t*. Then we establish a momental equation on the compression steel and another on the tension steel. If M_t equals moment of external force on tension steel and M_c is the moment of external force on compression steel, these equations would be as shown in the diagram on this page, and by simple transposition we get the reinforcement as:

$$A_c = \frac{M_c - c.\frac{b.n}{2}\left[d - \frac{n}{3}\right]}{v.[d-f]} = \frac{M_t - c.C_c.a_c}{v[d-f]}.$$

$$A_t = \frac{M_c + c\frac{b.n}{2}\left[\frac{n}{3}-f\right]}{t(d-f)}$$

$$= \frac{M_c + c.C_c\left[\frac{n}{3}-f\right]}{t[d-f]}.$$

As a check, or to avoid one momental equation, we may put it that

$$A_t = \frac{C_c + C_s + N}{t}.$$

Other equally simple methods are based on the division of the moment into two, one which is taken by the whole compression wedge and a part A_t of the tension steel, and a second to be taken by the remaining steel A_{t2} and C_3 with due regard to the direct axial force. (See Mörsch, Vol. II, page 438; Saliger, page 261; and Hager, "Theory of Reinforced Concrete," 1916, page 192.)

Mr. Reynolds rightly points out at the conclusion of this case that the equations may produce uneconomical figures for reinforcement. It appears in fact that we generally obtain more economical reinforcement if the tension stresses in the steel are not taken to the permissible limit. The explanation of this is as follows: Any increase in the tension steel increases the height of the compression zone and thus entails a reduction of the necessary uneconomical compression steel to an extent which counterbalances the increase in tension steel.

It is wrong, however, as stated, to think that the limit of economical design is reached when the compression and tension steels are of equal strength. Equally strong reinforcement is frequently used for practical reasons in supports, vaults, etc., but these structures cannot then claim to present the most economical solution for purely static reasons.

Case 4.—In determining the stresses in a given reinforced section, Mr. Reynolds again avoids calculating the position of the neutral axis. If *n* has been found in accordance with previous demonstrations, however, we readily obtain the stress

$$c = \frac{2N.n}{b.n^2 + 2m.C_3[n-f] - 2m.A_t.[d-n]}$$

and the other values in the usual way.

We believe, therefore, that from the foregoing we may make the following deductions :—

I am of the opinion that Mr. Reynolds goes rather too far in thinking that his method presents considerable simplification and that in his view the old methods used hitherto are only capable of solution by the use of complicated calculations and curves or tables. The values found by Mr. Reynolds by his method may just as easily be obtained by the old methods.

Unfortunately Mr. Reynolds does not say anything about those problems where the use of such curves and tables is indicated. I may, therefore, perhaps be allowed to point out that tables are used to avoid the troublesome solving of cubic equations for finding the position of the neutral axis, and that, above all, the graphs published by Mörsch provide a welcome simplification in determining the minimum total weight of steel for single and double reinforced sections and lead to the desired result with a minimum of laborious calculation. (In each case only the values

$$\frac{M_r}{c.b.d^2} \text{ resp. } \frac{M_t}{c.b.d^2}$$

are to be determined.) (See Mörsch, Vol. T2, page 407 and onwards.)

In conclusion, it may be mentioned that in practice there is another kind of problem, where the assumption of the correct axis is rendered impossible. This occurs in cases where the supporting structure is subjected to live loads (bridge arches, crane runways, etc.). In designing such structures we require to know the areas of influence and, as the moments are not always the decisive factor, we must find the areas of influence of the core moments.

At the beginning, however, we do not even know the correct core widths. Therefore we have to base our calculation of reinforcement on the core widths for the concrete section only. The stresses arising in the reinforced section and the reinforcement required for given stresses are then found by the aid of the stresses for the concrete section, the limits of which in the various methods of loading may be obtained by superposition. It would be wrong, however, to determine, for example, the limit stresses directly by superposition of the actually effective reinforced section for each individual method of loading, because the effective section will vary in each case and the superposition would therefore be invalid. As the limit values in the reinforced section may be assumed to arise under the same load as in the concrete section, the correct stresses may be found from the foregoing. (Compare Mörsch, Vol. T1, pages 420 to 422.)

Design of Formwork.

Owing to pressure on our space, we are unable to give Part XIII of Mr. A. E. Wynn's series of articles on "The Design of Formwork for Reinforced Concrete Construction" in this issue. The series will be continued in our next issue.

Reinforced Concrete at the Bedford Electric Power Station.

By J. R. BLAIKIE, M.I.Struct.E.

In common with many electric power stations, during the war the Bedford undertaking found it necessary to extend the works considerably to meet the pressing demand for power supplies to munition factories. It was thus in 1917 that an entirely new station was planned by Mr. R. W. L. Phillips, A.M.I.E.E., the Borough Electrical Engineer.

The first section, with the usual type of flat roof and comprising two coal bunkers of 100 tons each, proved to be thoroughly successful and economical in construction, the only drawback being the blocking of the engine room (which is about 42 ft. high from the basement) during the construction of the roof, and the time that must necessarily elapse before the centering could be removed.

New Electric Power Station at Bedford.

In 1920 a further section was added, with three additional coal bunkers each of about 100 tons capacity, but in this case the solid roof was replaced by a hollow-tile system carried on steel joists spanning the engine room and boiler house. In this way no obstruction was made in the engine room, and the work of erecting the plant could proceed without delay.

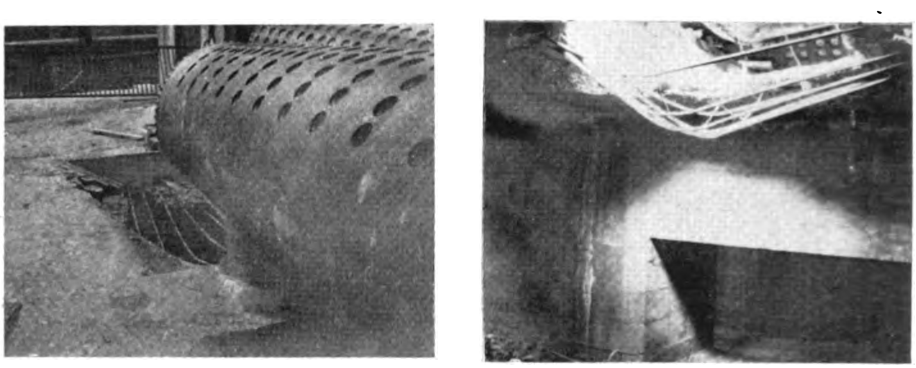
In 1924 a third extension became necessary, which is now nearing completion. The last addition will provide four new coal bunkers of similar capacity, and although the general arrangement of the original building scheme is maintained there are important modifications in the internal arrangement to accommodate larger types of plant, and economisers installed over the boilers. For example, two bunkers are carried on a single span of 25 ft. to allow for boilers of more than double the capacity of those originally installed, and the mid wall is provided with reinforced concrete stanchions in place of brick piers to carry the extra loading due to the overhead economisers and heavier crane loads.

The flat roof was in this instance carried out with hollow pre-cast slabs by Messrs. Siegwart Fireproof Floor Co., Ltd., on steel girders to avoid the obstruction in the engine room which would have occurred if centering for the usual solid slab had been employed. A further advantage gained is freedom from sweating, as the hollow slabs form a better heat insulator.

An interesting feature of the last extension is the use of rapid-hardening cement. It is rather more costly than the best brands of ordinary Portland cements, but the saving in shuttering by being able to release it in seven days should more than compensate the extra cost, and the general convenience of being able to clear away props and struts should advance the practice of reinforced concrete construction very considerably.

In the present work some very marked examples of the economy of reinforced concrete work as against steel construction have been observed. In the case of piers for the foundations of the turbo-alternators it is desired to have a considerable mass in order to resist vibration. Where two piers have to be bridged the contractors for the turbine recommended heavy compound girders which were to be embedded in concrete to obtain the desired mass. For these girders the quotation amounted to £102 7*s*. 4*d*. The turbine contractors, however, accepted a reinforced concrete design in place of the girders, when the cost of the steel amounted to £24 2*s*. 6*d*., the concrete and shuttering being the same in either case.

The superiority of reinforced concrete as against mass concrete construction



Top of Floor. **Underside of Floor.**

Effect of Fall of Drum weighing 3 tons 6 cwt. a distance of 17 ft. on to 4-in. Reinforced Concrete Floor. The ⅝-in. rods were unbroken.

was illustrated by an accidental seventeen-feet fall of a boiler drum weighing 3 tons 6 cwts. end on into an ashpit of reinforced concrete only 4 in. thick. None of the main reinforcement was broken, but stretched about 6 in. in length. In a similar accident elsewhere (though from another cause) a drum crashed through an 8 in. mass concrete floor and embedded itself in the ground underneath, in a basement. The damage done in the former case was quite trifling (under £10), and incidentally the drum was not injured, possibly due to the yielding of the reinforced concrete floor.

At the present time the building is 182 ft. 9 in. long, and has a total width of 81 ft. 4 in.; it contains approximately plant of 14,000 h.p., with overhead coal bunkers of about 900 tons capacity.

The foundations are carried out in mass concrete piers about 13 ft. below the basement level, where solid rock is found. Owing to the peculiar formation of the ground it was scarcely possible to use piles, as a strata of false rock and shale about 2 ft. thick is found on a bed of clay about 18 in. thick just above the solid rock.

The street frontage is carried out in brick and stone, presenting a substantial and pleasing appearance.

The contractors for the three instalments were :—

(1) Messrs. Moss & Sons, Loughborough; (2) Messrs. W. Greenwood & Sons, London; (3) The Luton Building Co., Luton.

The reinforced concrete designs were, 1st Instalment by Mr. H. de Colville; 2nd, by Messrs. E. P. Wells and W. C. Cocking; 3rd, by Mr. J. R. Blaikie, the first being checked by the late Mr. Chas. Meik and the second and third by Messrs. Webster and Fitz Simons.

A Concrete Scholarship.

Realising the enormous strides reinforced concrete has made in the United States, the British Portland Cement Association has founded a Travelling Studentship to the value of £300 a year. The Scholarship will be awarded by the Institution of Structural Engineers, and the winner will be required to travel in America for two months and on his return write a paper on the lessons he has learnt from his tour. Further particulars of the competition will be published in due course.

Reinforced Concrete in the Restoration of Reims Cathedral.

In view of the doubts in the minds of many British architects as to the propriety of using reinforced concrete in the preservation of ancient monuments, it is of interest to note that the French have unhesitatingly adopted this material for the restoration of the roof of Reims Cathedral, which was so badly damaged during the war.

The restoration of the roofs covering the north and south aisles to the nave of the cathedral are already completed as far as the transepts. The Administration of the Ministry of Fine Arts has adopted, for the restoration of these roofs, a system of construction in reinforced concrete in order that there shall be no repetition of the fires which destroyed the old work.

It may be noted that the wooden roofs of several other cathedrals in France have been replaced by cast-iron or reinforced concrete. The system of construction adopted for the Cathedral of Reims was used for the first time in the new roof at the Church of St. Jacques, in the same town. It consists of a light frame-work, built up of "planks" of reinforced concrete, pre-cast in the cathedral itself, and of such dimensions and weight that the assembling of the pieces together can be done by one or two workmen without mechanical aids or lifting machinery of any kind.

These planks of reinforced concrete are cast on the spot in simple wooden boxes. Tenons and mortices are made as required for the assembling of the planks together. The same moulds being used for all the planks, permits as many to be cast as are required, without any delay in execution, as the moulds are removed as soon as the casting is completed. As a result of this method there is a very considerable saving in shuttering, while at the same time the adoption of one standard section for the planks, all of which have the same dimensions (approx. 1⅝ in. by 7⅞ in.), makes it an easy matter to cast any length required. Also, the reinforced concrete planks can be either slightly curved or quite straight as desired, which allows for all possible combinations. The assembling of the planks of reinforced concrete is carried out by means of the tenons and mortices, which are blocked out in the moulds when casting, and the different pieces are secured in the erection of the truss by keys and purlins, etc., so arranged as to secure lateral rigidity and vertical continuity.

This method of construction, by reason of the multiplicity of the joints, allows not only for the easy removal and replacement of any one plank, but also provides a requisite amount of play at each joint, and thus overcomes the difficulty of expansion and contraction. Some of these junctions may, if desired, be sealed either with plaster or with cement mortar. The joints in the longitudinal line of each truss are free to allow for expansion and contraction.

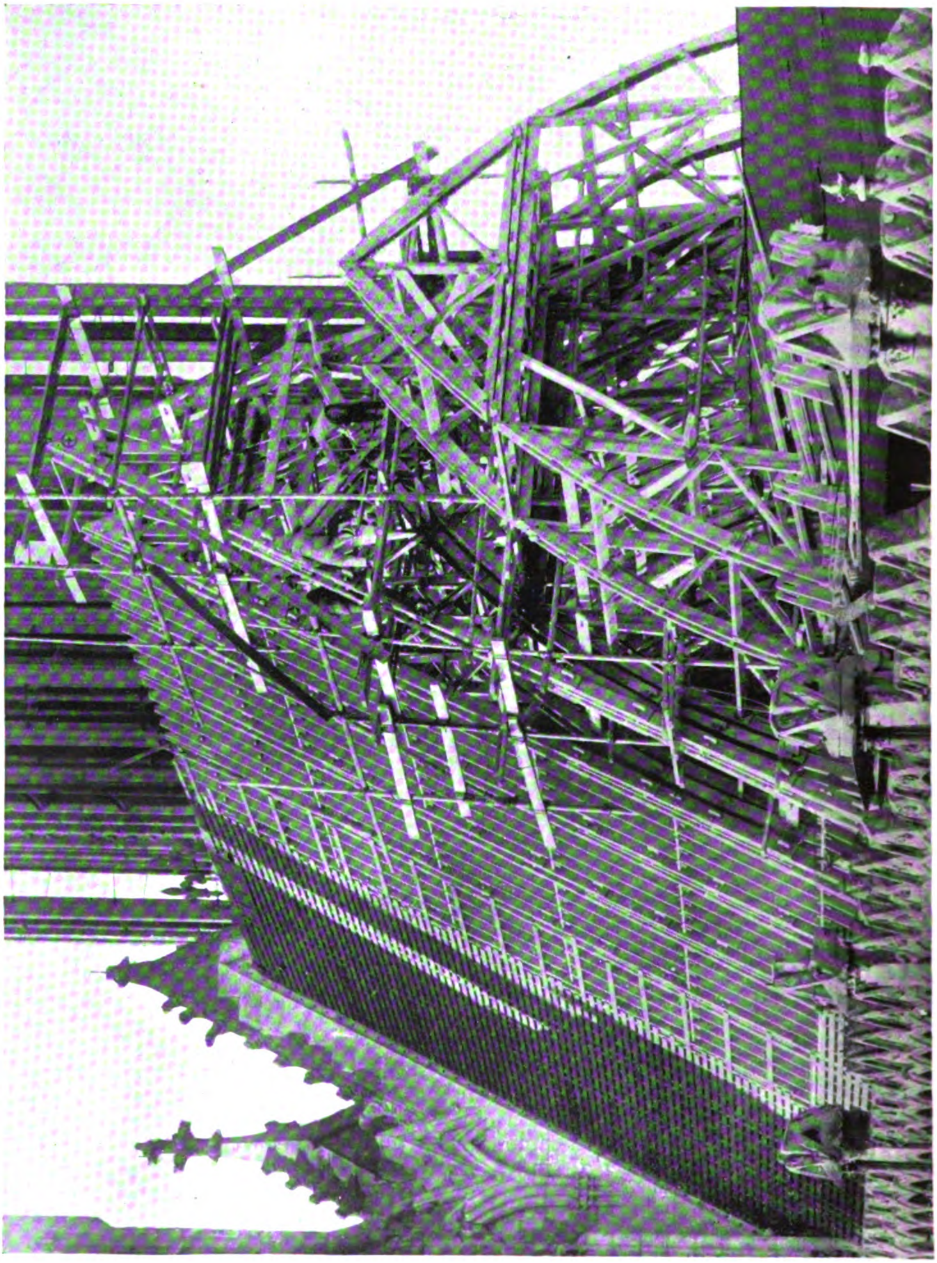
Tests made on a single truss of the roof of the Church of St. Jacques showed that an evenly distributed weight of ·12 tons was safely supported on the two *arbalétriers*.

A similar method of construction has been used for the roofs over the aisles of the cathedral. This advantageously replaces the old roof-trusses in wood of heavy and inconvenient design, which made it difficult to obtain access to the inside of the roof over the vaulting below.

The new reinforced concrete roof has been so designed as to be entirely separate from the masonry of the vaults below, and the obstruction caused by the old massive tie beams, plates, etc., now no longer exists, as the principals, purlins, and rafters are all in the same plane.

The slight thrust is evenly distributed between the flying buttresses by a long horizontal beam which externally forms the gutter at the springing of the roof.

With this method of construction, made up as it is of a large number of elements of small section, it is necessary so to arrange the roof construction as to make each piece of it do the requisite amount of work in order to preserve the necessary resistance of the whole to pressure—the involuntary result is that the design reminds one considerably of the construction of a mediæval roof in wood, where each "*chevron portant fermé*" was complete in itself and added no weight to the



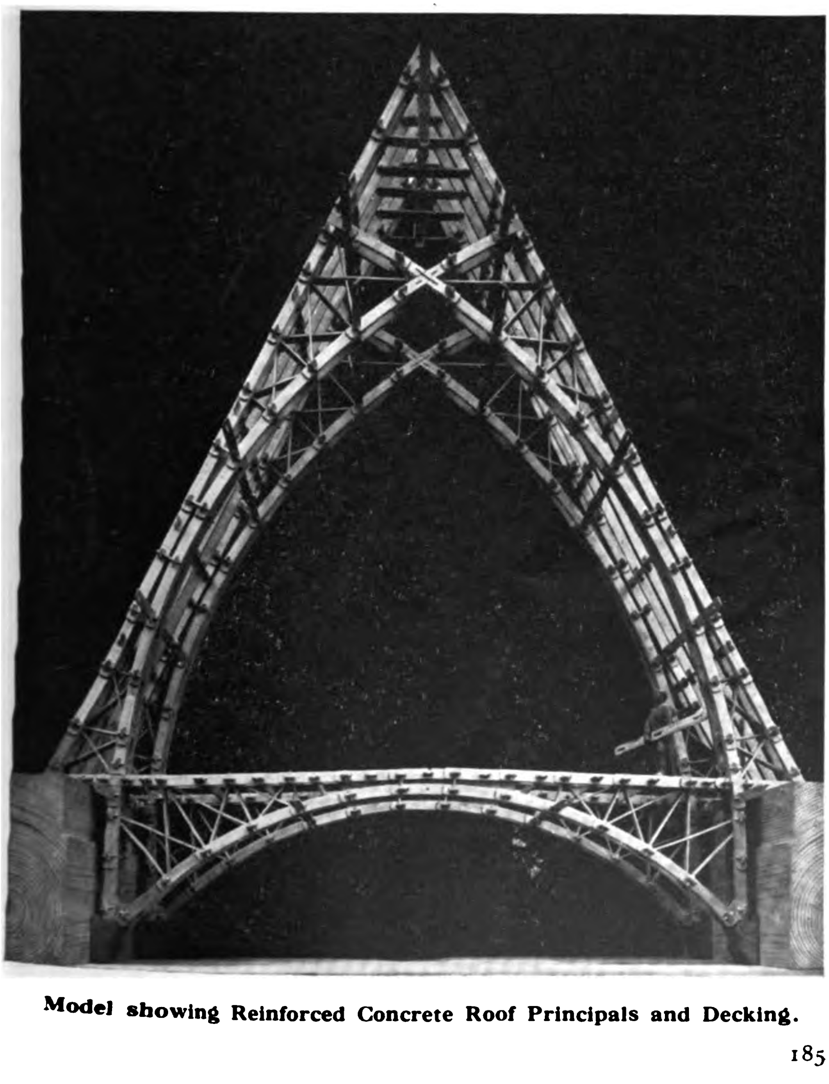
Restoration of Reims Cathedral: General View of New Reinforced Concrete Roof over Nave.

real trusses, which served only as stiffeners at certain intervals.

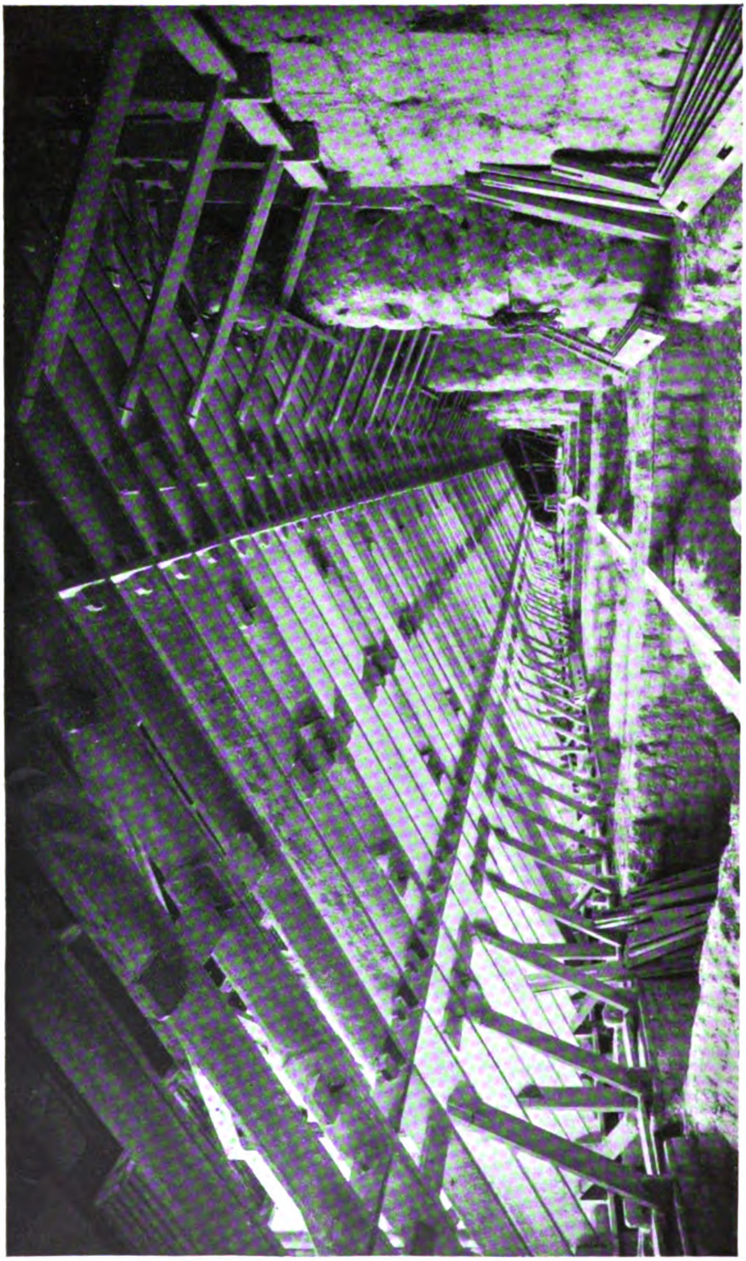
The design approved by the Ministry of Fine Arts to give effect to the intentions of Mr. Rockefeller (in his gift for the reconstruction of the roof over the nave) is also inspired by the ancient arrangement, as Monsieur Deneux, the architect for the work, was opposed to the idea of reproducing in reinforced concrete the ancient carpentry of the fifteenth century. This would have loaded the walls with a weight three times greater than that of the old wooden roof.

The new roof, entirely in concrete, will not weigh any more than the roof it is designed to replace ; it may even weigh rather less when completed ; and, notwithstanding the great number of pieces, the total cube of the reinforced concrete employed does not exceed one-third of the cubical contents of the old wooden roofs. At the level of the parapet of the external walls there will be a ***plancher de service*** inside the new roof, which is supported by a series of arched trusses, built up of the reinforced concrete planks described.

The main roof will be composed of twenty-three similar trusses. This work



Model showing Reinforced Concrete Roof Principals and Decking.



Restoration of Reims Cathedral : New Reinforced Concrete Roof over North Aisle.

in reinforced concrete will be not less than 62 ft. in height from the extrados of the vault to the ridge.

For reasons already explained and on account of the small section of the planks of which they are built up, the trusses have been placed at frequent intervals, being only about 7 ft. 9 in. centre to centre, so that to each bay of the vaulting below (measuring about 23 ft. 6 in.) there are three roof trusses.

The new roof will be covered externally with lead about ⅝ in. thick, and in sheets some 9¾ ft. long by 2 ft. wide, laid on battens, about 4 in. by 1 in., placed about 3 in. apart. The old roofing was arranged to prevent trouble from condensation of moisture on the inner surface of the lead, due to changes of temperature. The lead sheets will be run in trays of sand, as was done in mediæval times, and not in laminated sheets. The old ventilating dormers, with their ornamental lead finials, the ridge cresting of fleur-de-lys alternating with trefoil ornaments, similar to that which previously existed before the Revolution, are also included in the programme set by Mr. Rockefeller.

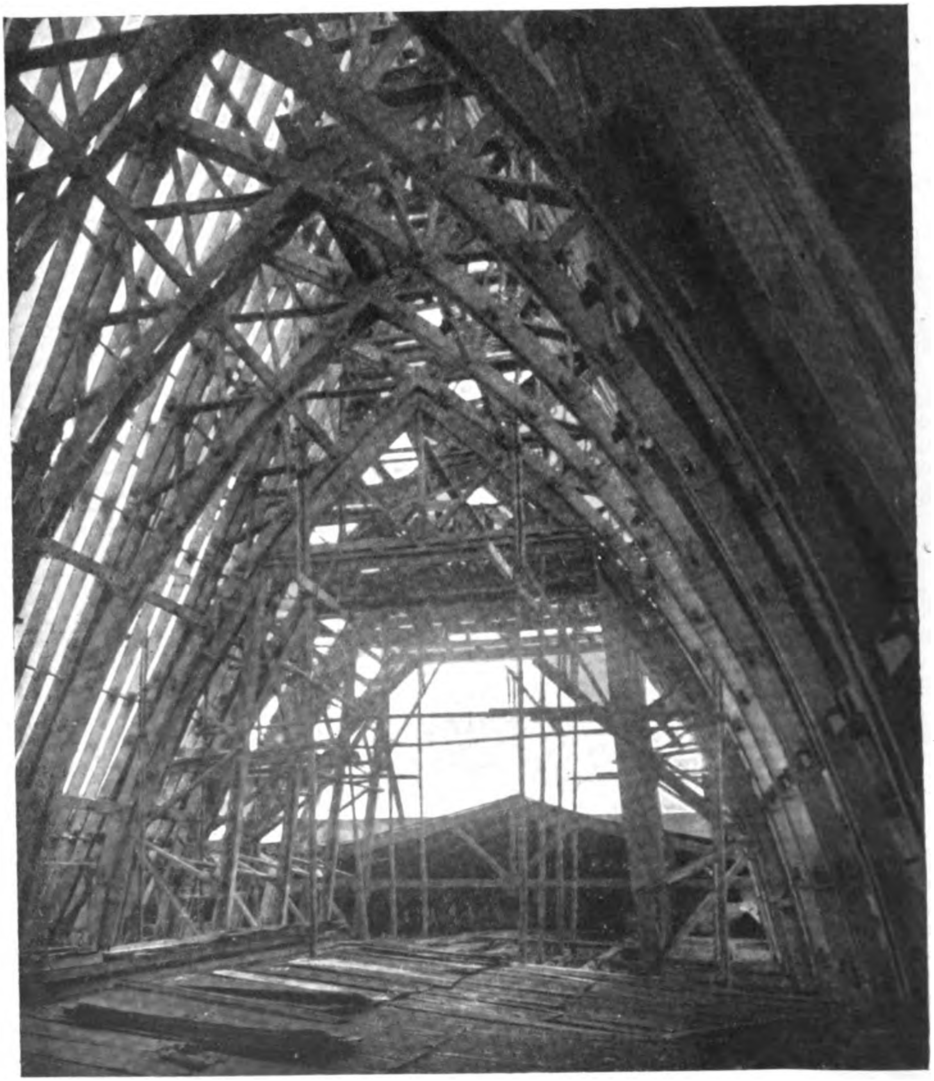
Grouting at Lincoln Cathedral.

At a recent meeting of the Royal Institute of British Architects, Sir Charles Nicholson and Sir Francis Fox, the architect and consulting engineer for the restoration of Lincoln Cathedral, described the work now going on. The cracks and fissures which threatened the stability of the structure are being grouted with Portland cement in the same manner as was adopted at Winchester Cathedral a few years ago, and both Sir Charles Nicholson and Sir Francis Fox testified to the efficacy of the method.

In the course of his remarks, Sir Francis Fox said much to his surprise the masonry of the western front was found not to be properly bonded in with the towers and there were serious cracks existing for the whole distance of 200 ft. and for the height of 100 ft. The result was that the entire front was showing signs of falling in a westerly direction on to the greensward of grass—like the cover of a book. Notwithstanding all precaution, the towers continued to settle, and the cracks which were in the old work grew larger and spread in different directions. In 1820 heavy iron cramps were applied to prevent further mischief by the spread of the fissures in the towers. These bars were 1 in. thick and 4 in. broad, the inside ones being carried through the wall at both ends, and through a corresponding bar outside and screwed to it by a powerful nut. Five of these hoops, both inside and outside, were attached at proper distances between the roof of the church and the top of the towers. About six tons of iron were thus used on each of the west towers.

It was intended to take off these iron bands as the repair work proceeded. Two at the highest point had already been removed. Several of these iron bands were broken in two ; in some cases there was a distance of 2 ins. between the broken ends which clearly showed spreading of masonry. In other cases the bolt that carried through the wall had broken immediately behind the nut ; some of the nuts had fallen to the roof below ; others that were so rusted in, had stayed in their position, thus giving a false impression of security. In addition to the iron bands some hundreds of iron wedges had been used to level up the courses of the masonry that had dropped owing to the spreading of the tower walls. The destruction produced by wrought iron to masonry was almost incalculable, as it was laminated ; when the corrosion took place the laminations gradually opened, and by slow expansion the whole mass of masonry was either lifted or broken off. In some cases, hundreds of tons of masonry were being lifted or forced from their original position. There were cracks to-day from 1 in. to 6 in. wide running practically the full width from the south-west corner of the west front to the south-west angle of the north-west tower. These cracks, prior to the present repairs, carried right across the north-west tower to the extreme north end of the west front. One crack at 90 ft. up was 12 in. wide and was now made good.

In 1921 the arches in the bellchamber opened to such an extent that the archstones had to be strutted to prevent their falling out. Also the ribs of the vaulting of the north-west vestibule had dropped,



Restoration of Reims Cathedral: Internal View of New Reinforced Concrete Roof over Nave.

so that instead of their being concave they were convex and at the point of falling to the ground.

Owing to the continued spreading of the cracks in the walls, to-day there was not to be found a single bonding stone intact. Each one showed fractures from ⅛ in. to 2 in. wide. The tower walls were split in almost every possible direction, vertical, horizontal and longitudinal with the wall faces. In 1924 the two sub-arches immediately above the vaulting of the lantern had collapsed to such an extent, owing to the four main lower arches spreading, that the weight of the masonry above was actually bearing on the vaulting of the lantern, and as that was only a very light construction, intended merely to carry its own weight, it was showing serious fractures.

All of this dislocation had now been made good and completed to the clock-chamber floor, 125 ft. above ground level.

The system of grouting by pressure employed in the work was that invented by the late James Greathead. An air-compressing plant for machines in any part of the cathedral, and for delivering water, also by compressed air, to any height of the building which was above the limit of the city water company was laid out by Mr. Godfrey, the clerk of works, who also introduced jack hammers and chisels, and the employment of delta metal as tie rods, thus avoiding the objectionable results of using iron and steel which one saw throughout Lincoln and St. Paul's Cathedrals. The nuisance of covering the whole fabric with dust was also prevented.

The sounding of the walls to discover the presence of hidden cracks was effected by gentle tapping with a one-pound hammer throughout the entire fabric and wherever it indicated cavities the necessary application of the nozzle and the forcing in of cement under pressure (delta metal ties having been previously placed in position) immediately rendered the walls sound and solid. In many places the masonry blocks were neither bonded nor tied in, and wherever visible cracks existed they were carefully investigated, for although perhaps only an inch in width was externally visible, they might prove to be anything up to 10 or 12 in. in the interior.

Owing to the transept walls buckling, the vaulting had flattened to such an extent as to show cavities from 4 to 5 in. in width between the vaulting and the main walls, up and down each cell to the full length of the transept. These cavities were not previously located, as a great many others were, owing to their being full of accumulated dust and débris.

Owing to the extensive amount of grouting that would be required and the thickness of the walls to be penetrated, in some cases 20 ft. thick, a motor-driven air-compressor was purchased, but it was soon found that, owing to the looseness of the rubble core, some method less costly and also less dangerous than the ordinary hammer and chisel must be applied to enable them to get the grout right into the hearting of the walls.

To this end jackhammers, driven by compressed air, were purchased. These tools had proved to be most effective from every point of view. It was nothing unusual for two men to drill a hole in the walls to a depth of 12 ft. in one hour, in what would otherwise require the same number of men five to six days with the ordinary hammer and chisel method. This was not the only point to be considered. The condition of the masonry was almost at the point of collapse, and would not stand the heavy blows of the hammer; whereas the jackhammer, although it made a terrific noise in working, gave a percussion blow with very little jar to the building. By these means they had drilled into the masonry of the north-west tower up to October 28, 1925, 11,774 holes, approximately 5¾ miles in length, and the number of holes in the centre tower and transept was 10,623, approximately 3½ miles, making a total of 9¼ miles.

By that method of grouting they were able to repair the most ancient and beautiful buildings, without in the least degree defacing their antiquity. At the same time they practically rebuilt them, making them many times stronger than they were when first erected, without so much as moving a stone.

The same improved method of grouting, and the drilling of the walls by the jackhammers, which originated at Lincoln, had been adopted and were being carried out at Durham Castle, St. Paul's Cathedral, and elsewhere.

There was a great deal of controversy for and against grouting. There was bad as well as good grouting. Unless the method was carried out in a right and scientific manner, the state of the walls sooner or later would be worse than before. The proper order was first to blow out all dust and dirt from the loose core, then thoroughly to wash out with water under pressure, continuing to blow water in until it ran out of the surrounding places quite clean. While the core was still damp, and in a receptive condition, the cement grout must be blown in also under pressure. This was varied according to requirements, 40 lbs. to the sq. in. being the average employed. If the core were not thoroughly cleaned, one simply filled the void and the cement would not adhere; consequently one added weight without adding strength to the building.

In addition to the grouting up of the cracks, they were reinforcing the masonry with delta bronze cramps. These varied from 9 in. to 14 ft. in length, and ¼ to 1 in. sq., and had a tensile breaking strength of 30 tons per sq. in. Up to October 28 inclusive they had inserted 5,406 cramps in the north-west tower and 2,961 in the central tower and transepts, a total weight of 13 tons 4 cwts.

The zig-zag lines in the masonry showed that the north-west tower was split right through from top to bottom. These cracks were equally as bad on each of the other three sides. In fact, the tower was split from floor to roof into a number of separate sections, trusting entirely for support to broken iron bands and bolts and fractured wood tie beams. To prevent any possibility of further spreading of the tower walls, they had (in the passages in the thickness of the walls) constructed strong reinforced concrete beams. Six had been provided at various heights, the top one forming the roof-plate. The four octagonal turrets were anchored to each of these beams, well braced at the angles. It was estimated that each of these beams would stand a strain of not less than 800 tons. It was intended to carry out the same method of bonding the four walls together in the central tower. One beam was completed in the lantern and the reinforcement was in position ready for the concrete in the clock chamber, 125 ft. above floor level. A similar beam had also been constructed on the clerestory passage floors, in both north-west and south-west transepts.

At different periods some of the cracks which were of easy access had been filled in with pieces of stone and pointed up with mortar. In two particular instances the soffit of the two arches that had collapsed at some time, some 100 ft. above floor level, had been filled in with blocks of wood, and actually tightened with wood wedges, then plastered over with mortar, and lined out to imitate masonry.

Up to October 28, 1925, they had forced into the walls and surroundings of the north-west tower 22,944 gallons of grout, equal to 3,671 cubic ft. of space, and weighing approximately 104 tons, and into the transepts and the central tower 10,372 gallons of grout equal to 1,659 cubic ft. of space, and weight 47 tons. What with the grout, the constructing of the reinforced beams, and rebuilding of the masonry in different parts, and reinforced concrete floors, they had used a total of 446 tons of cement and 471 tons 19 cwts. of sand. To September 30, 1925, 2,177 new stones, equal to approximately 1,766 cubic ft., had been used.

That did not mean that they had increased the total weight of the building: far from it. Against that they had to calculate the hundreds of tons of débris, old timbers and ironwork which had been removed.

The proper sequence of operations in repairs of this character was as follows:

(1) To shore and timber up the walls, and to centre the arches, in order to relieve them of as much weight as possible, and also to prevent any broken pieces of stone from falling.

(2) To wash out with water, and grout up from the bottom with cement, the masonry or brickwork, rendering the whole mass monolithic so that any operation may be as free from risk as possible.

(3) To replace broken masonry and to insert the necessary bond stone.

(4) When all this had been done, steps might be taken to strengthen the foundations.

It was evident that to alter this sequence in any way was to court disaster; not a stone should be moved nor cut open, even to remove old rusty ironwork, or rods, until all grouting was done.

Owing to the modern application of compressed air, they were making considerable saving in the total cost, which in some cases amounted to only one-twentieth of that under the old methods of hand labour.

Ryde Pierhead Reconstruction.

For many years before the "grouping" the London & South Western and the London Brighton & South Coast Railways had jointly maintained a passenger service to the Isle of Wight from Portsmouth to their pier at Ryde, and this service has been developed by the Southern Railway so that it is still by far the most patronised of any of the routes to "The Island." During the summer season, from July 12 to September 20, 1925, over half a million people landed or embarked at Ryde Pier, while the number of passengers on the August Bank Holiday week-end—Saturday, Sunday and Monday—exceeded sixty-four thousand.

The pier at Ryde runs out some half-a-mile to sea in a nearly northerly direction, and consists of three parallel viaducts terminating in a common head. The westward viaduct represents the original pier, one of the oldest in the country, but reconstructed some while since. The central pier carries an electric tramway, claiming to be the first in this country. The pier which carries the double railway track, and which is generally spoken of as the "Railway Pier," though all are now the property of the Southern Railway, is a heavy steel structure at the east and was the last to be constructed. These three piers have a common head some 650 ft. from east to west and 250 ft. across at the widest part, having 9 ft. 6 in. of water alongside at low tide.

This head provided berths for five steamers, of which three were fitted with steam cranes for handling luggage; full accommodation for smaller boats, motor launches, yachts, etc.; the usual range of offices required at a terminal station, and large concourse, giving access to the three platforms. A typical cross section shows that the pierhead was of a substantial type and well fitted for the traffic.

Here, however, *Chelura Terebran* are very active, and the cost of maintaining a wooden pier is very high. The average life of a pitch-pine pile does not exceed twelve years, despite every effort to counter the ravages of the worm. This, coupled with the fact that the regular service of large paddle-wheel steamers in all weathers at an exposed pier must do a certain amount of damage, explains why despite the driving of between five and six hundred new piles in the last eighteen years the condition of the pierhead was not considered satisfactory. A small section of the area in front of the two earlier piers had been reconstructed just after the war.

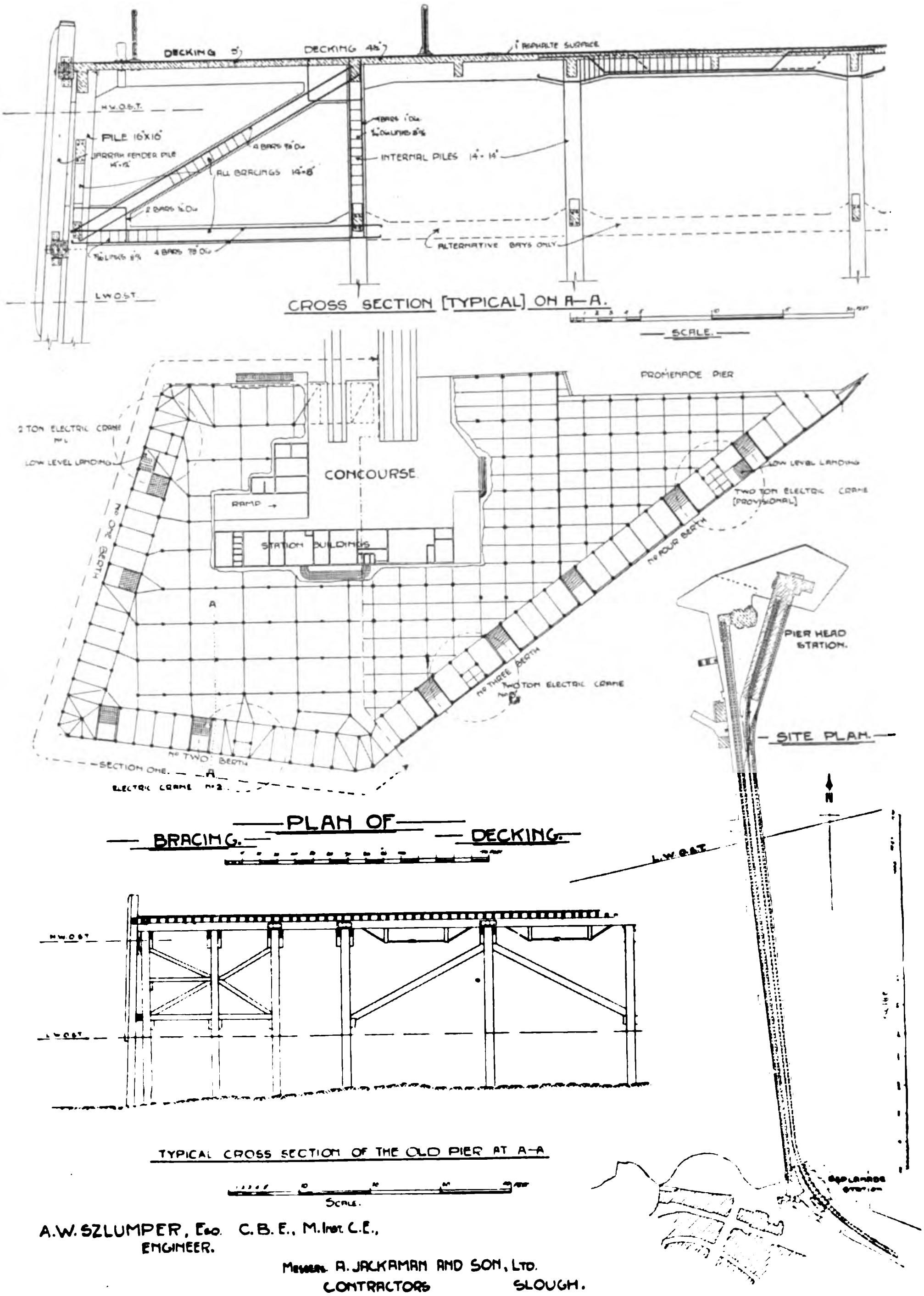
The Joint Railway Company (S.W. and B.S.C.) decided, therefore, to reconstruct in reinforced concrete, to the designs of the Chief Engineer of the L. & S.W.R. Company, Mr. A. W. Szlumper, C.B.E., M.Inst.C.E., four of the steamboat berths and nearly the whole area of the pierhead, the contract being placed in the hands of Messrs. A. Jackaman & Son, Ltd., of Slough, for the work on the Hennebique system.

No interruption of the normal flow of traffic could be permitted, so it was decided to divide the area to be reconstructed into two nearly equal portions, as shown in the drawing, and of these the eastern, and very slightly larger portion, was first put in hand. A start was made on No. 2 Berth, thus allowing No. 1 Berth and the whole of the station buildings to remain in use longer than would otherwise have been possible. Actually No. 1 Berth was used for the summer traffic of 1923.

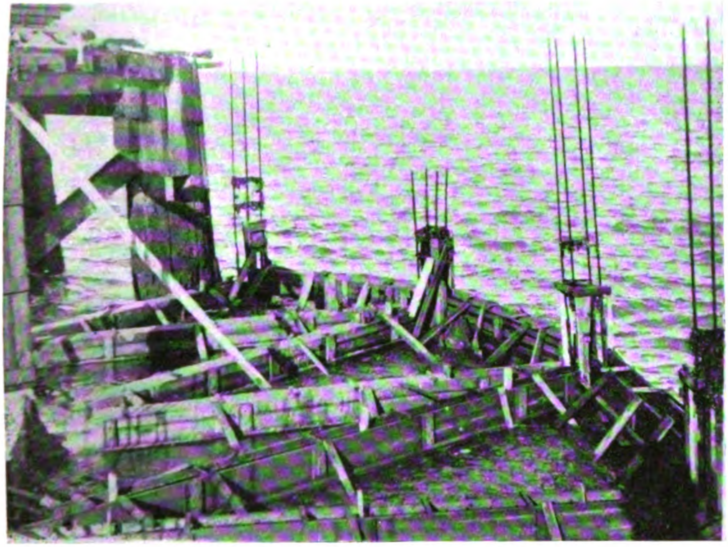
The contractors had at the date of commencing the contract an established pile-yard at Southampton in connection with another contract they were carrying out for the Southern Railway—dolphins for a 60,000-ton floating dock—and no suitable yard being available in Ryde arrangements were made for the moulding of the piles at Southampton.

The experience gained in the constant replacing of the timber piles in the old pier showed that 55-ft. timber piles could be relied upon to finish about deck level or above, hence it was decided to prepare for use in Berth 2 a first batch of reinforced concrete piles 60 ft. long, the heads of which it was expected would finish also about deck level. Certain delays arose, as it was decided to take advantage of the opportunity offered by complete reconstruction to bring the pier faces forward a little and so allow re-spacing of the face piles to be carried out regardless of the stumps and old and worm-eaten piles.

The contractors installed for the purposes of the work a 10-ton derrick crane



Reconstruction of Ryde Pierhead.



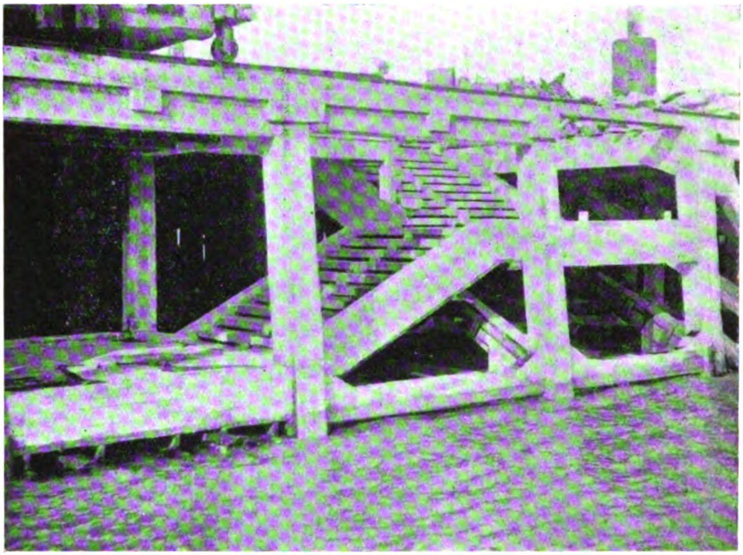
Bracings at the North Angle.

with 80-ft. jib mounted for travelling. The existing pier was not strong enough to carry the heavy point loads from plant of this nature, and staging piles for this purpose were driven in a series of "strong points" for each working position of the crane, and connected by roads strong enough to carry the crane when passing from one working position to another. These "strong points" were so arranged that the staging piles could be recovered for re-use from each succeeding position. Simple as the process may seem, great care had to be exercised owing to the very poor condition of parts of the pier where in some cases the piles were eaten right through and swung from the decking they were intended to support, while in other parts pile after pile was eaten down to 3 in. or so in diameter and any side-strain would cause complete failure. Despite these difficulties, and as the result of careful handling, no failure resulted during pile-driving.

As shown in the drawing, the whole scheme involves some 312 reinforced concrete piles, and of these the front piles are 16 in. by 16 in. in section, reinforced by four $1\frac{1}{4}$ in. diameter rods and with pre-formed twisted links of $\frac{3}{16}$ in. diameter steel, generally spaced at 8 in. centres—but gradually closed up towards the head and toe to a minimum of 2-in. centres; 14 in. by 14 in. piles are used generally elsewhere, and in this case the four corner bars are 1 in. diameter with four handling bars through the middle length of the pile $\frac{7}{8}$ in. diameter and 30 ft. 6 in. long, the whole being linked up as before. In both cases the skeletons are kept taut by cast-iron spreaders. Cast-iron shoes weighing 60 lbs. each are fitted, the toe of the shoe being recessed at the base to receive the main reinforcement of the pile. A mixture of 7 cwt. of cement, 27 cu. ft. of stone, and $13\frac{1}{2}$ cu. ft. of sand was used for the piles.

Actual pile-driving was started in Berth 2 on July 7, 1923, and it was at once found that the expected results would not be obtained. A long series of experiments followed; a longer trial pile was driven, "chogging" was tried, and lengthening and redriving, and redriving after a period of repose were among the various expedients put to a practical test. "Cement Electrique" tried in pile lengthening gave most unsatisfactory results, failing under driving stresses in every case save one.

Finally it was decided to mould future piles 5 ft. longer, viz. 65 ft. long, and to drive them to 11 ft. below deck-level, thus giving an effective increase in length of 16 ft. without any considerable increase in the percentage of reinforcement required. Not only did the delay this



Low-Level Landing.

reconsideration involved retard the piling, but the subsequent building of the superstructure became of a different and much slower nature.

Fortunately only 70 piles had been ordered, and the remaining piles were prepared of the new length to enable the piling of Berth No. 2 to be completed. Berth No. 1 was vacated and piling started there on January 8, 1924. The longer piles proved to be no more satisfactory than the 60-ft. piles, judged by recorded sets at the conclusion of driving, but they were perfectly satisfactory when loaded after a period of repose and it was decided to drive all future piles to a level and rely on the "stiction" set after repose.

The contractors had found that two 50-ft. by 12 in. by 12 in. pitch-pine piles about 30 ft. in the mud, and having a set of 4 in. a blow with a ton solid monkey falling 6 ft., could be relied upon to carry without settlement the king-post load and reaction of their derrick-crane equal to about 50 tons, and further tests confirmed this in a very definite manner, hence the reinforced concrete piles with a yield of 2 ft. in thirty blows of a 2-ton steam monkey falling 18 in. have been incorporated as satisfactory.

As in the second portion of the work the whole of the area to be reconstructed could be handed to the contractors at once, it was decided to mould the piles for that section on the decking. This involved certain strengthening work to make the pier secure, and this was carried out, piles being driven as necessary and recovered later.

Twenty piles were prepared clear of traffic while this portion remained in use, to facilitate as early a start as possible, but the remainder of the piles were moulded with rapid-hardening Portland cement and driving was thus possible after 14 days. The experience of this material has been most satisfactory. This section was handed to the contractors on March 24, 1925, the first pile was driven on April 8 and the driving completed on September 2.

Piling being advanced, the superstructure was put in hand, the bracings, etc., being all moulded *in situ*. Bracings were 13 ft. below deck level, 14 in. by 8 in. in section, and reinforced by four $\frac{7}{8}$-in. diameter rods linked with $\frac{1}{4}$-in. diameter all-round links at suitable intervals. Trouble was experienced from wave action, which destroyed some work, but on the whole little damage has occurred. The bracing was, of course, tidal, and could not be executed at all during the neap-tide period.

The reinforced concrete piles had been spaced everywhere to clear the existing piles. It was not always possible that the bracing should also clear, but wherever possible the bottom work was pushed ahead before more of the older pier than necessary was dismantled, the old work thus serving as a staging for the purpose of constructing the new work. Afterwards the decking joists and trussed timbers were dismantled, and any other timber which fouled the beams or decking of the new pier removed. Subsequently the remainder of the timber was recovered and the piles cut off; the piles would have become dangerous if left in owing to their worm-eaten condition—hence the removal of the whole structure. The plan gives a general idea of the arrangement of the bracings, while the typical elevation shows the details.

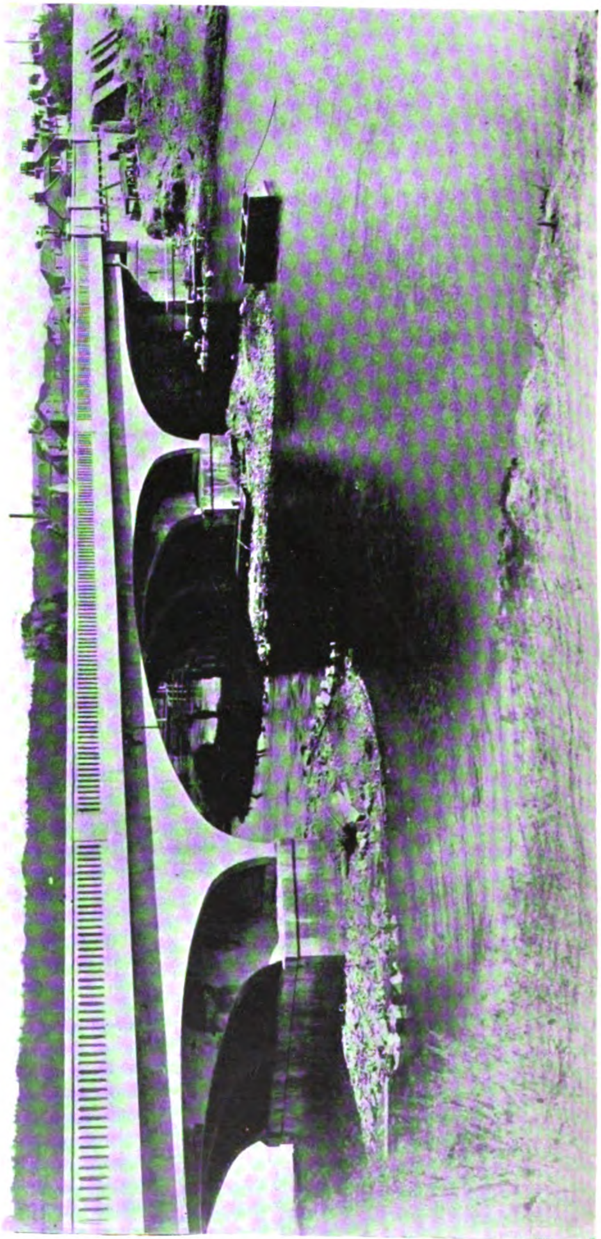
The piles are, of course, extended *in situ* as columns for the support of the beams and decking. At a usual bay the main beams, 20 ft. span, are 16 in. by 8 in. with four 1⅛ in. diameter rods, while the transverse beams, 15-ft. span, are 12 in. by 6 in. with three ⅞-in. diameter bars. The decking is calculated for a loading of ¾ cwt. per super foot, and is generally 4½ in. thick. The floor bays are 20 ft. by 15 ft., divided into two equal areas 15 ft. by 10 ft. for slab purposes, each slab being reinforced by ⅜ in. diameter bars, two curved and one straight, 5 in. centre to centre with ¼-in. diameter top bars at 12-in. centres. Special bays are dealt with as necessary; thus at the face all bays are increased to 5 in. in thickness, while at the cranes and certain exposed corner bays a 6-in. floor is provided. These bays are, of course, suitably reinforced.

Under the station buildings and concourse the general floor level is some 3 ft. higher than elsewhere to conform to platform level. Access is given to this high level by two flights of steps in reinforced concrete, cast monolithic with the floor for the use of passengers, and two ramps for luggage cages. The variation of levels, etc., causes some beams to be of unequal size, every beam being considered on its merits. In the floor and beams are formed all the necessary ducts for the electric lighting and power for the electric cranes, fencing, and drainage, attachment of bollards, rubbers, etc., and at the edge a curb is formed to serve as a stop to the surfacing. At intervals as required there are formed round the pier two low-water landings and stairs, seven half-tide landings, and one special boat landing. These are indicated on the plan. In these cases the steps and landing slabs were pre-cast, this being the only work of that nature in the pier.

The fendering of the pier was the subject of much consideration. The destructive worm in the water limited the choice of wood, but in the end Jarrah piles 55 ft. long by 14 in. by 12 in. in section were decided upon. On account of their length these were specially imported from Australia. Low-water walings and chogs are of the same timber, but the gunwale above high-water is in pitch-pine. The fender piles are carried up about 3 ft. above the decking, as at exceptional high water the sponsons of the boats are above floor level. The Jarrah piles are protected by elm rubbing strips at the faces to take the blow from the steamer.

The whole of the work now in hand will, it is anticipated, be finished for Easter 1926.

Silicate of Soda and Concrete.—Messrs. Brunner, Mond & Co., Ltd., write: "In the literature upon various methods of curing concrete, 'curing with silicate of soda' is sometimes referred to. It should be pointed out that this method consists essentially in painting the surface of freshly-made concrete with a strong solution of silicate of soda in an attempt to prevent loss of moisture from the mass during its early life. The silicate of soda applied in this way forms a glass-like skin on the surface of the concrete and does not penetrate to any appreciable extent. The use of silicate of soda for this purpose should not be confused with its use in the form of a very dilute solution for case-hardening the surface, as the two processes are entirely different. In the latter case the solution, owing to its high degree of dilution, is enabled to penetrate the surface layers of concrete to a depth of perhaps half an inch and deposits colloidal silica and calcium silicates in the voids without leaving a skin of unchanged silicate of soda on the surface."



Reinforced Concrete Bridge at Inverurie. (*See p.* 197.)

Reinforced Concrete Bridge at Inverurie.

One of the most notable features of the royal burgh of Inverurie in Aberdeenshire was the old stone bridge across the River Don, now replaced with the reinforced concrete structure illustrated herewith.

Before proceeding with the demolition of the old bridge, which was built in 1791, Messrs. Tawse & Allan, of Aberdeen, the engineers for the new bridge, endeavoured to obtain information as to its construction in order to help them in its demolition, and thus gained a considerable knowledge of the history of the structure. At the request of the committee in charge of the reconstruction of the bridge, the engineers prepared a history of the structure to be buried in the new bridge as a record, and the results of these investigations have now been published by the engineers in book form. The matter makes quite a large volume, well-printed on good paper, and copiously illustrated with views showing the various stages in the demolition of the old bridge and the construction of the new one.

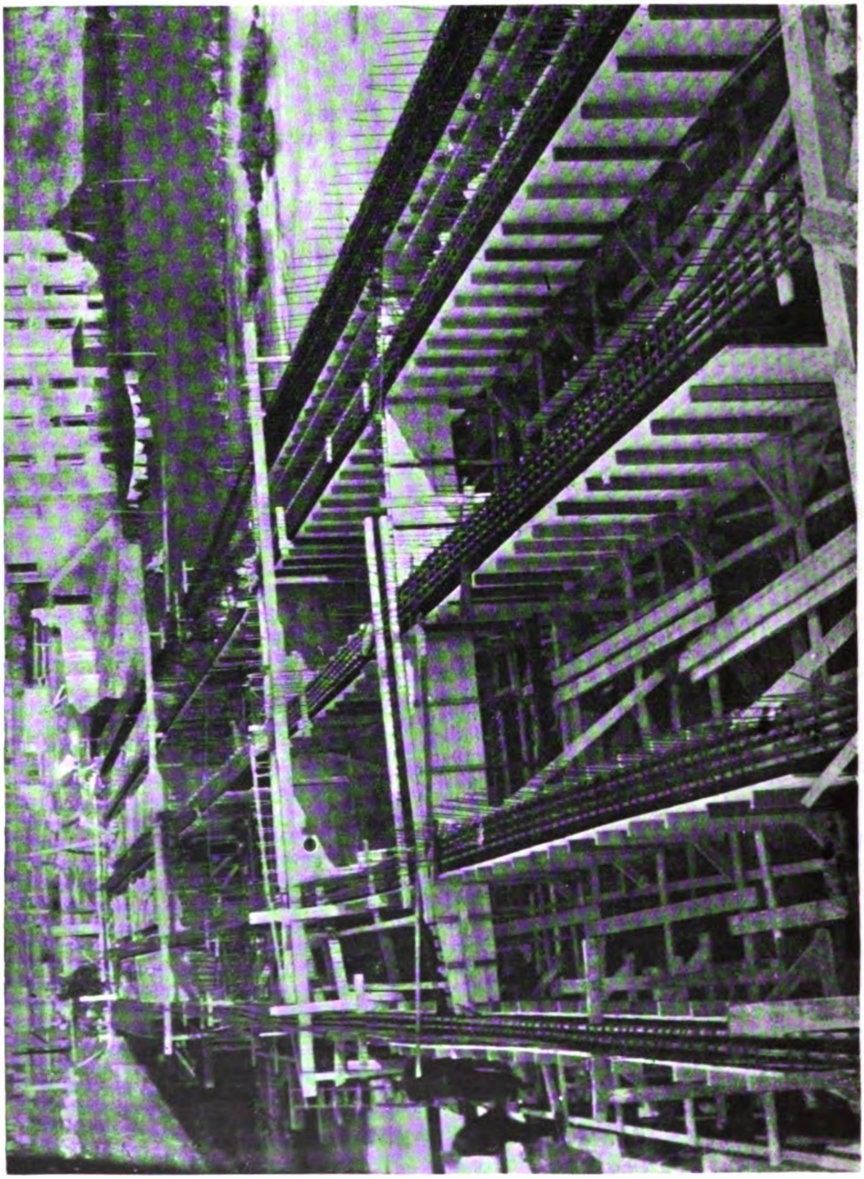
The old bridge had a length of a little over 200 ft., and a width between parapets of 15 ft. The centre span is 62 ft. 6 in. and the outer spans each 57 ft. 3 in. The piers are 12 ft. 6 in. wide. These dimensions are the same as for the old bridge, on the foundations of which the new structure has been erected, with the exception that the width between parapets is now 35 ft. (20 ft. roadway and two pavements of 5 ft. each). The total cost of the reconstruction was £14,985. In order that concreting might proceed during cold weather, the two mixers were connected to a boiler supplying hot water for mixing. Perforated steam pipes were also led from this boiler through the piles of sand and aggregate, which were heated before mixing. The concrete used was a 1 : 1½ : 3 mix of Portland cement, sand and ¾-in. granite chippings.

In order that the weight of the new structure should fall symmetrically about the foundations both longitudinally and laterally, and to prevent any twist in the finished structure, a scheme for the depositing of the concrete was worked out which allowed for completing the girders and the deck slab in 10½ working days, to the following schedule: First day, part of centre girder, 25 cub. yds.; second day, remainder of centre girder, 31 cub. yds.; third day, part of the two intermediate girders, 40 cub. yds.; fourth day, remainder of the two intermediate girders, 29 cub. yds.; fifth day, the two outside girders, 21 cub. yds. From the sixth day onwards the formation of the deck slab was proceeded with in sections, four at a time, working from the piers outwards, about 40 cub. yds. per day being placed. While the body of the bridge was maturing the east and west pavement slabs were cast, the concrete kerb formed, and the approaches carried out.

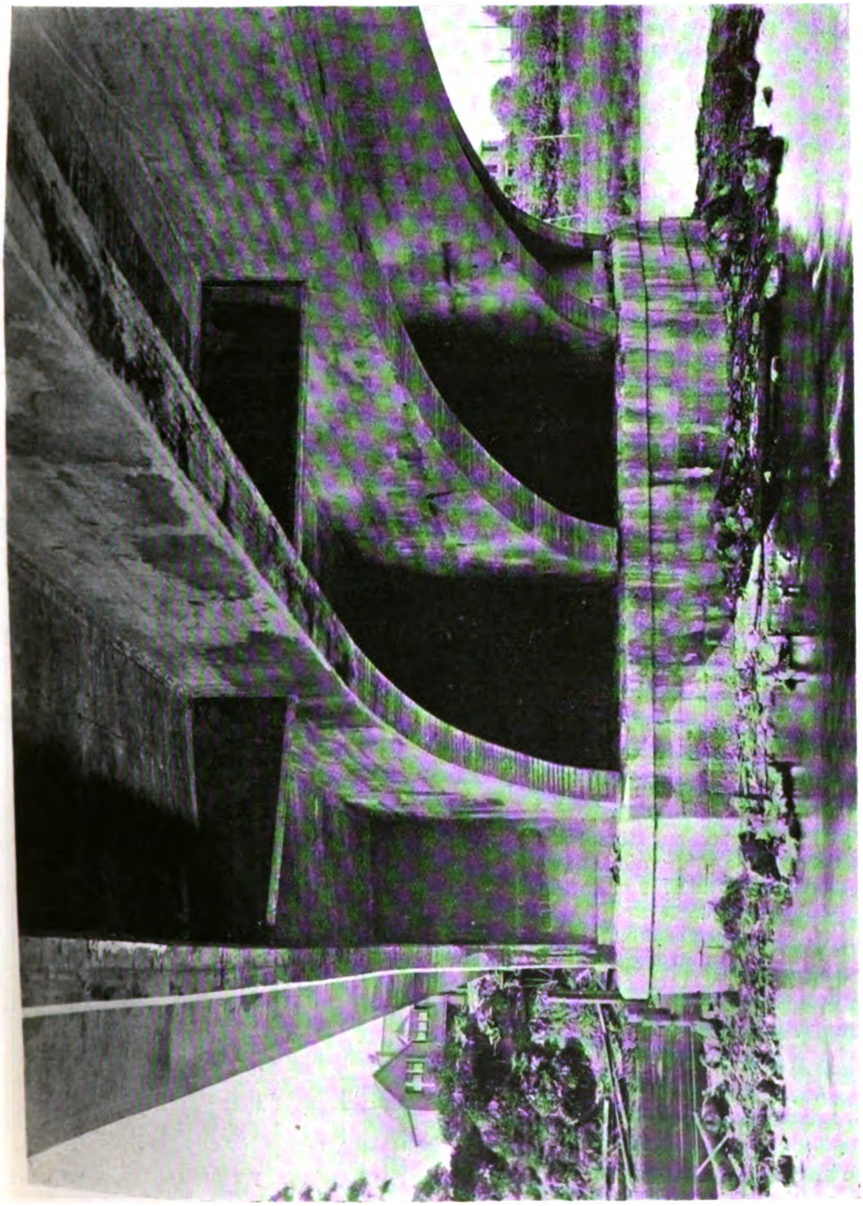
The balusters of the parapet were cast sixteen at a time in steel-lined moulds so made that they collapsed and left the green balusters, with the reinforcement projecting, to be carried away to cure. After being matured for four days, the balusters were rubbed perfectly smooth and to true surfaces and edges with carborundum blocks. Mortar was rubbed into the surface pores, and the surplus mortar removed with clean water.

After the beams forming the base of the parapets had been poured and set, the anchoring pilasters were cast in place and the balusters set in line in the groove in the plinth beam left for the purpose. The balusters were set in lengths of about 20 ft., and the joints clayed up, and cement grout forced by compressed air into the groove, completely filling the space between the balusters and the plinth. After all the balusters were jointed the coping was poured, thus making the balustrade a monolithic structure.

The two free ends of the bridge were formed at a level half-an-inch higher than their finished level, and after the bridge had matured the ends were freed and lowered into their final positions. In the wedging-up of the ends, four steel wedges, in pairs, one above the other to form flat surfaces on top and bottom, were set on each of the three beds on which the bearing plates would eventually rest. The three inner girders rest on the abutments, but the two outside girders have no bearing on the abutments. The bearing plates were in the form of a square made up of two inner



Reinforced Concrete Bridge at Inverurie: Reinforcement of the Five Main Girders.



Reinforced Concrete Bridge at Inverurie: Underside of South Span.

plates of copper and two outer plates of steel, each set being wrapped in oiled silk to protect the plates from the concrete and supported on the top surfaces of the wedges. Wooden boxes made to the exact size required were filled with sand to their full depth of 1¾ in., and on this bed of sand short boards were placed to form the under-surface of the lateral girder connecting the five longitudinal beams. The concrete was allowed nine weeks to mature, and after the framing was removed the steel wedges were left in position for a further three weeks. Several methods were tried to effect the withdrawal of these wedges; amongst others a hydraulic jack capable of lifting 200 tons was tried and proved ineffectual. As the wedges projected some distance beyond the two parts of the bridge which they kept separate, their ends were forced apart and the top ones levered outwards. This proved to be the successful method. After the removal of the wedges the ends of the bridge took an hour and a quarter to settle down on their concrete foundations.

It is not often an engineer gets an opportunity to publish such an account of his work, and Messrs. Tawse & Allan are to be congratulated on the excellent manner in which they have compiled and presented this interesting history of a landmark which will be missed and account of the erection of its successor.

The reinforced concrete design is by Messrs. Considère Constructions, Ltd.

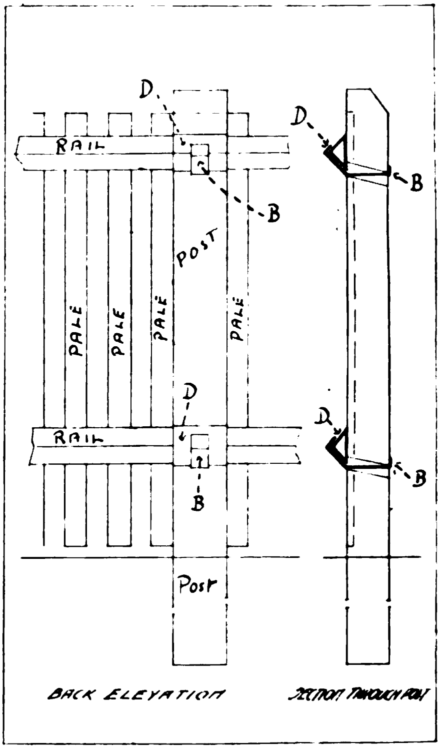
Concrete-and-Wood Fencing.

THE method illustrated of fixing wooden rails to concrete posts has been designed and patented by Mr. Clifford S. Banks, L.R.I.B.A., of Highfield House, Oakfield Road, Croydon. With the usual type of wooden fence, constructed of posts, rails, and boarding, the first parts to rot are the posts at ground level and the ends of the posts where they are mortised to the posts. The use of concrete posts eliminates the first difficulty, but owing to the draining of water into the post owing to the diminishing for mortising the second still remains.

As will be seen from the drawing, in this new system the rails are not slotted through the posts but attached to them by means of a galvanised iron sleeve and clip. The full size ends of the rails are pushed into the sleeve D on sketch, the clip B is pushed through the mortise hole in the post and the sleeve and rail pushed through the clip, when the weight of the rail gives an automatic fastening. The two pales next adjoining the concrete post are then fixed tight up to the post, which gives a permanent fixing to the whole when the remainder of the pales are fixed in the ordinary way.

When once fixed it is impossible to remove any part of the fence until the two pales adjoining the posts are removed, and if necessary to remove any panel there is no need to take the fence to pieces, or interfere with the posts, as if the two pales adjoining the concrete posts are taken off the panel may be lifted out bodily.

The method does not necessitate any bolts or other parts which can become rusted and impossible to re-use in the case of repairs. Gravel boards can be fixed, removable in a similar manner to rails.



Tests on Concrete.

By V. E. GREEN, A.M.Inst.C.E.

In the course of a paper read before the Institution of Civil Engineers (Birmingham and District Association) recently, entitled "Tests on Concrete," Mr. V. E. Green, A.M.Inst.C.E. (Industrial Research Laboratories, Birmingham Corporation Gas Department), described a series of tests carried out on concrete blocks, using a good quality of ordinary Portland cement, and also "Ferrocrete" rapid-hardening cement. The tests were commenced towards the end of October, 1924, and twelve months' tests on the concrete cubes have been carried out.

The aggregate used consisted of Birmingham Tame and Rea District Drainage Board sand and gravel, used in the proportion of 1 part cement, 2 parts sand, and 4 parts gravel. Special note should be made of the water content, as it was intended that the concrete made should represent that which could be easily produced under practical conditions. The amount of water used was 11 per cent., and there seemed to be no doubt that if a lower water content had been used and the cubes had been made under strictly laboratory conditions the crushing strength at a low age would have been much higher.

TESTS ON RAPID-HARDENING PORTLAND CEMENT.

Tensile Strength after 28 Days' Immersion in Water. Standard Sand and Cement (3 : 1).

Breaking Load—Lbs.						Average Breaking Load. Lbs.	Minimum Load required to pass British Standards.
A.	B.	C.	D.	E.	F.		
640	742	634	729	644	580	662	$583 + \frac{10{,}000}{583} = 600$

The aggregates and sand were carefully measured by volume, using a 6-in. cube measure. The cement in each case was carefully weighed, the volume proportions being based on the assumption of 90 lbs. weight per cubic foot of cement. The water in each case was carefully measured in a calibrated pint measure, the water being obtained from the town main.

The sand and aggregate were mixed together on the floor, the cement being added next, and then all finally mixed, using an ordinary shovel. The water was then poured into the centre and also sprinkled over the mass, which was afterwards thoroughly mixed. The mixture was placed into six of the 6-in. cube machined cast-iron moulds in turn, being slightly tamped with a hand rammer. The mixing and moulding of the six cubes took about 15 or 16 minutes from the time of adding the water. The top surfaces of the cubes were scraped off and finally flattened about an hour after filling in the moulds.

The blocks for 1, 2, 3 and 4-day tests were taken out of the moulds at periods of about 18 or 24 hours after moulding, being placed on the floor and covered with a damp bag. Those for 7-day tests and upwards were taken out of the moulds about a day after moulding and completely immersed in water (about 62° F.) in the laboratory.

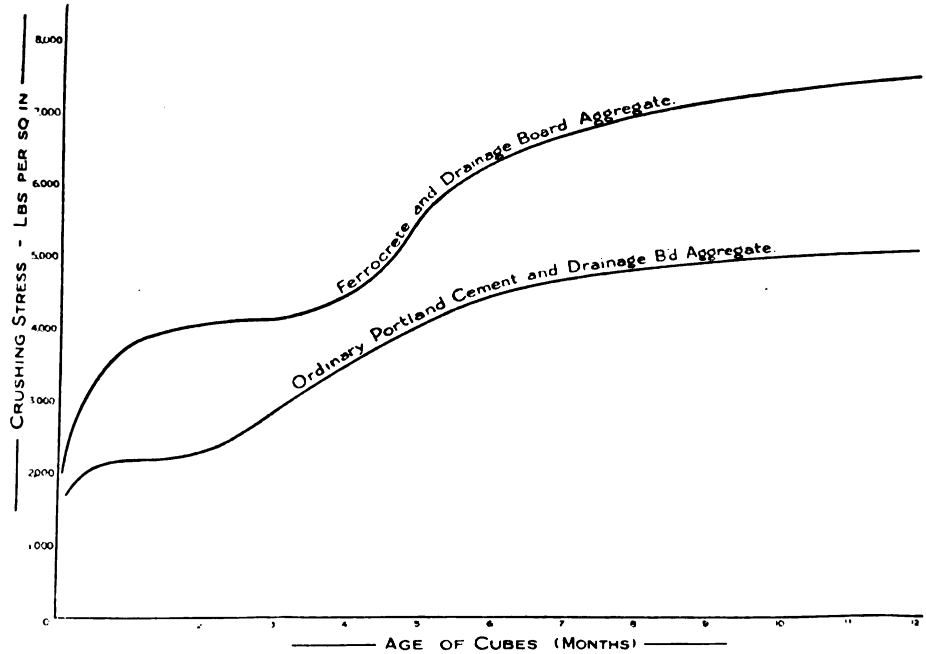
Compression tests were carried out in an Avery 100-ton single-lever vertical testing machine, electrically driven, the rate of loading being arranged at about 15 tons per minute. The cubes were tested so that the thrust took place in a direction at right-angles to the way in which the cube was moulded, so as to use the flat and parallel surfaces.

During the testing of each cube the load at which first visible cracking took place was noted, and also the final collapsing load.

Tests were also made for setting time and tensile strength of 3 to 1 sand-cement briquettes, in accordance with the usual British Standard Specification.

In the ensuing discussion Mr. Whitehead (Engineer of the Tame and Rea District Drainage Board) asked for relative strengths of concrete made with round and crushed gravel aggregate.—The author replied that in many cases compression test results showed no difference between the two aggregates, but in a few isolated cases about 10 per cent. extra strength was obtained with the crushed aggregate.

Mr. Overfield (Birmingham City Sur-



Compression Tests on 6 in. Concrete Cubes made with Rapid-Hardening and Ordinary Portland Cement (4:2:1 mix).

veyor's Department) mentioned that the water content of the concrete mixture was rather on the high side, and asked if any "slump test" figures had been taken during the making of the concrete cubes. —The lecturer pointed out that the high percentage of water used was for the purpose of making concrete under practical working conditions, and also that the sand and gravel used for making the blocks were themselves in a dry state.

Mr. Veal (Lecturer in the Civil Engineering Department, Birmingham University) asked whether the curves represented one series of tests or accumulated data from all laboratory tests. He also thought that the 1,000 lbs. per sq. in. figure for the compression strength of a 4 : 2 : 1 concrete at 7 days was, if anything, on the low side.—A reply was made to the effect that the curves shown represented a definite complete series of tests, and not a collection of haphazard tests.

Mr. White (Assistant Engineer, Birmingham Canal Navigation Company) mentioned the advantages which the new cement would undoubtedly give in new construction and repairs to existing bridges. He also asked what was the relationship between the strength of the concretes at 28 and 7 days respectively.—The reply was that an American publication had recently given the following figures for the relation between the 28 and 7 days' tests :—

$$f_{28} = f_7 + 30\sqrt{f_7}.$$

The author had found from the Industrial Research Laboratory tests, using ordinary Portland cement, that the following ratio was more applicable :

$$f_{28} = f_7 + 22\sqrt{f_7}.$$

Major Cook (Ministry of Transport) asked how the test cubes were stored.—Reply : All blocks were immersed under water in a tank in the laboratory at a temperature of about 60° F., the minimum temperature of the water not falling below about 50° F.

The Chairman (Mr. H. P. Raikes, Consulting Engineer, of Birmingham) said he was very keen on practical tests of concrete, but also agreed that the tests carried out were of extreme importance in giving engineers ideals to aim at. He had found the clay content of aggregate lower the compression test results, and said it was necessary to have even faces on the test cubes. He thought the new cement might lead to great economy in concrete construction.

American Concrete Road Construction.

By **R. A. B. SMITH, A.C.G.I., A.M.Inst.C.E.**

FURTHER to his article on concrete roads in America in our January issue, Major R. A. B. Smith, A.C.G.I., A.M.Inst.C.E., gave some further notes on the subject at a meeting of the Institution of Structural Engineers last month.

The first stretch of street paving in concrete was, he said, laid down in Bellefontaine, Ohio, thirty-three years ago to stand up to heavy loads of lumber, and that crossing was still in use.

The Courthouse Square in the same city was paved with concrete in 1893–1894.

The condition of traffic in the United States was one of the first things that impressed one. The streets were full of motor-cars and the number of lorries was far greater than he had been led to expect. The congestion was so great that in the actual city boundaries the control by light signals was absolutely essential, otherwise it would be impossible to proceed at more than a walking pace. On leaving the city boundaries there was still a large volume of mechanical transport for about twenty-five miles out of that city, after which it gradually decreased. In consequence the roads which really had the worst test were not so much the city roads, but rather those outside which had to stand not only the same weight of traffic as the city streets but the additional speed.

Nearly all the traffic was rubber tyred, as the law insisted on this being the case and, generally speaking, the width of the tyre was in direct relation to the total weight of the vehicle when loaded, ranging from 400 lbs. per inch for a tyre of 3 ins. to 800 lbs. per inch for a tyre of 14 inches.

Impact.

In tests carried out by the Bureau of Public Roads with solid-tyred and pneumatic-tyred vehicles the following conclusions were reached:

Impact depended largely upon the kind and condition of the tyre.

Thin or worn solid rubber tyres, even though they were very wide, produced very high impact forces.

Pneumatic tyres offered the greatest influence in reducing impact forces, and with their use impact increased only very slightly with the speed of the truck.

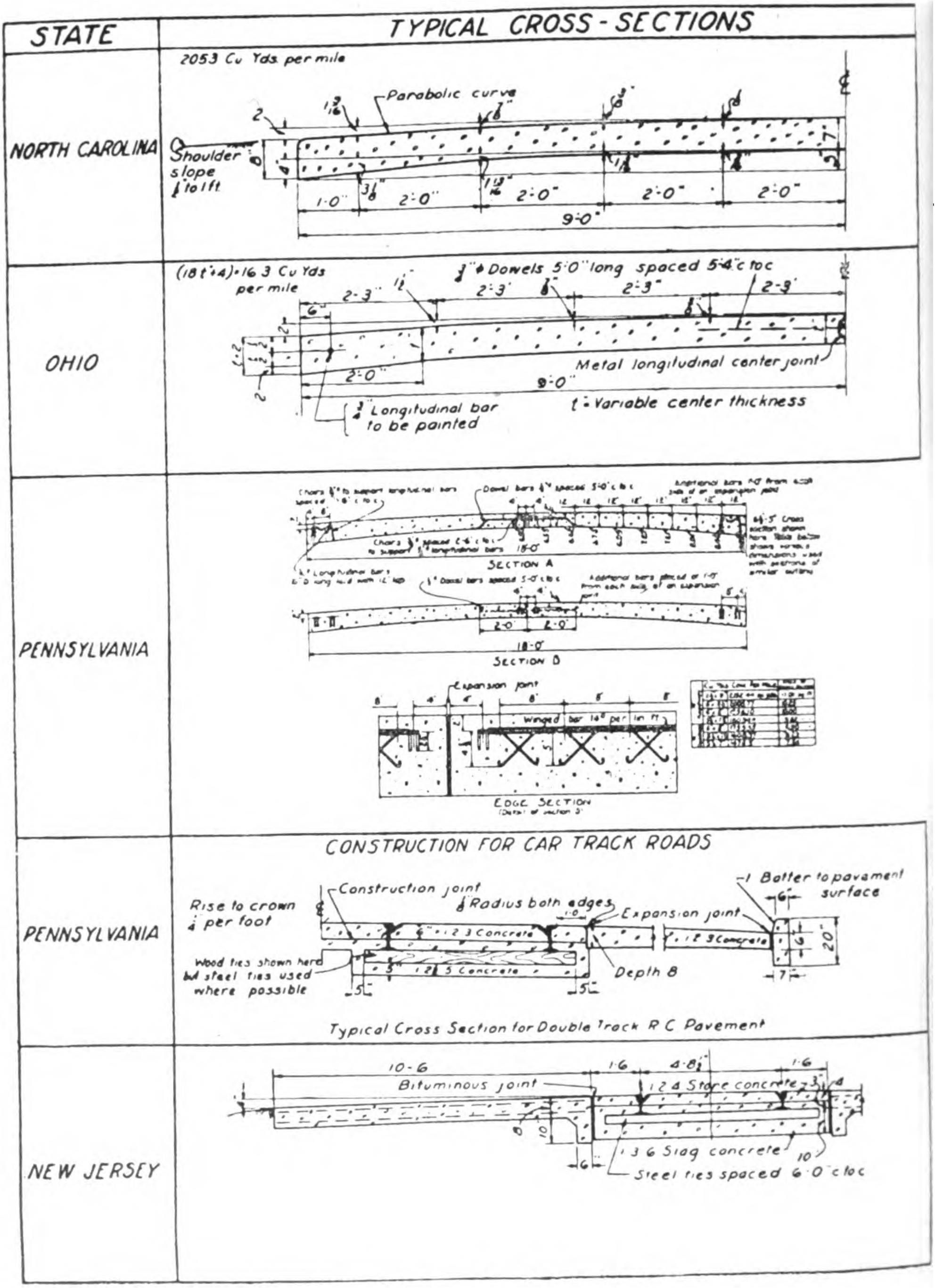
Impact might be as high as seven times the static load on one rear wheel when a solid-tyred truck struck a 1-in. obstruction at 16 miles per hour, an average value being about four times. For pneumatic tyres the maximum impact value was probably not more than 1¾ times the load at one rear wheel, and an average value was not more than 1¼ times the load.

In some experiments carried out at the Iowa State College Experiment Station it was found that the running and maintenance costs of solid-tyred lorries running over the best type of Portland cement concrete road was 3·875 pence per ton mile, and about the same for sheet asphalte. For pneumatic-tyred lorries running at 15 miles per hour the cost was 3·85 pence per ton mile; for well-maintained bituminous macadam the costs were 4·25 and 4·4 pence respectively; for well-maintained waterbound macadam 4·35 and 4·475 pence; for gravel roads the costs were 4·25 and 4·4 pence. From which it would appear that pneumatic-tyred lorries only claim a distinct advantage over solid-tyred trucks, as far as road wear was concerned, on good concrete or sheet asphalte roads. These figures, however, could not be regarded as final. They did not conflict with the statements made on the subject above as, of course, impact would not be felt on the roads when in very good condition.

The principle adopted by each State was to allow the Engineer so many thousand dollars a year to be spent on new construction. The Engineer was then free to collect his own staff and obtain the best results possible without any interference. For instance, in Wayne County there were some 42 assistant engineers engaged on concrete road construction.

Width and Thickness.

At first 14 ft. was considered sufficient width for the permanent paving. This rapidly became 16 ft., then 18 ft. and


STATE
TYPICAL CROSS-SECTIONS
NORTH CAROLINA
2053 Cu Yds per mile
Parabolic curve
Shoulder slope 1/2 to 1 ft
1-0"
2-0"
2-0"
2-0"
2-0"
9-0"
OHIO
(18 t+4)·16.3 Cu Yds per mile
3/4" Dowels 5-0" long spaced 5-4" c to c
2-3"
2-3"
2-3"
2-3"
6"
2-0"
9-0"
Metal longitudinal center joint
3/4" Longitudinal bar to be painted
t = Variable center thickness
PENNSYLVANIA
Dowel bars
18-0"
SECTION A
SECTION B
2-0"
2-0"
18-0"
Expansion joint
Winged bar 14" per lin ft
EDGE SECTION
PENNSYLVANIA
CONSTRUCTION FOR CAR TRACK ROADS
Rise to crown 1/4" per foot
Construction joint
3/8 Radius both edges
1-0
Expansion joint
1 Batter to pavement surface
6"
1:2:3 Concrete
1:2:3 Concrete
1:2:5 Concrete
20"
6"
7"
Wood ties shown here but steel ties used where possible
Depth 8
5"
5"
Typical Cross Section for Double Track R C Pavement
NEW JERSEY
10-6
1-6
4-8 1/2
1-6
Bituminous joint
1:2:4 Stone concrete
1:3:6 Slag concrete
10
6
Steel ties spaced 6-0" c to c

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finally 20 ft., which was the minimum width demanded to-day. Changes had also taken place in the depth of the concrete. To start with 5 in. was sufficient for the light vehicles using the roads, but as more and more roads were completed heavier vehicles came on to them for which they had never been designed, and now the depth of concrete adopted was, generally speaking, about 8 in. for main roads with lesser depths for the side roads.

It would be seen from this in districts like California and Delaware, where the mechanical traffic had not yet been increased to any great extent by lorry traffic, the depth of 6 in. was still adhered to, but even here the edges had been thickened.

The thickening of the edges of the concrete roads was interesting. Concrete altered in length due to the changes of temperature and moisture, and the effect of the former was greatest at the top of the slab. Consequently there was a greater change in length on the top of the slab, and it tended to warp. At night the slab cooled more rapidly on the surface than at the bottom, and the tendency was for the edges and corners to lift up and part from the subgrade. These facts were proved by the Pittsburg and Bates' tests and others. It was obvious that a heavy lorry hitting the edge of a thin slab which had become separated from the subgrade would tend to break it. Hence the design adopted.

The author was of opinion that United States engineers had forgotten the fact that due to heavier traffic they had thickened the centre of the roadway to such an extent that any additional thickness of the sides was now unnecessary and, as a result of inspection of various roads, he came to the conclusion that those built in New Jersey 8 in. thick throughout were as crackless as those in Wayne County, which were 8 in. thick in the centre and also thickened at the edges.

Reinforcement.

The general tendency in design was to use reinforcement about 1½ in. to 2 in. from the top, whereas in this country reinforcement was usually placed at the bottom of the concrete. There was considerable food for thought in this fact. The reason for putting reinforcement in the top was that the engineers of the United States considered there was more risk of failure in the concrete slab due to the movement of the subgrade than was likely to occur from impact of motor traffic. If this were the case the maximum tensile stress would certainly occur in the top portion of the slab, except when the road was being laid over rather bad ground, such as a peat bog; the slab was then deflected to such an extent by a heavy load that tensile stresses of some magnitude must occur in the lower portion of the slab. It was, therefore, quite credible that in future design in this country the best results might be obtained, under normal circumstances, by using reinforcement both top and bottom, when constructing roads over boggy ground.

The reinforcement was held in position by stirrups of the same material, bound to the longitudinal rods with copper wire. In a typical case the longitudinal rods were at 1-ft. intervals and the transverse rods at 1 ft. 6 in. intervals; the diameter of the bars being ½ in.

Mesh reinforcements were now being used in the States much the same as in this country.

What was known as continuous construction was now very uncommon; in fact, it might be said to be confined entirely to Washington D.C.

On the Pacific coast, where there were many miles of concrete roads, the cost of steel was prohibitive; in consequence, expansion joints were placed at 20-ft. intervals, and also down the centre of the road where the width did not exceed 20 ft.; for greater widths they were placed at 10-ft. intervals longitudinally.

Over the remainder of the country where steel was available at a reasonable price the expansion joints were 40 and 50 ft. apart; the former where the range of temperature was extreme, the latter where it was not quite so great.

Let us assume a concrete road 8 in. thick.

Let s = tensile strength of the concrete when failure takes place.

Let f = the coefficient of friction of the slab of the sub-base.

Just before failure takes place $s\ d \times 12 = L \times f \times w$ where d is the depth of concrete.

$$\text{Or } L = \frac{s \times 12 \times d}{f \times w}$$

Let $d = 8$ in.
Let $f = 2\cdot0$.
and $s = 100$ at 10 to 15 days.
Then

$$L = \frac{100 \times 12 \times 8}{2\cdot0 \times 100}$$

$= 48$ ft.

The above spacing assumed that no shrinkage or contraction took place until the end of ten days. If there were insufficient curing, or too low a temperature occurred, at the end of 24 hours the tensile strength of the concrete would be only about 50 lbs. per sq. in. and transverse cracks would occur between 20 and 30 ft. apart. It was apparent, therefore, that using ordinary British Portland cement this curing should be strictly adhered to.

Allowing the above assumption it was equally obvious that when using rapid-hardening Portland cement no further curing was necessary after 24 hours in ordinary weather, or three days when temperatures were very low. The use of rapid-hardening Portland cement for this form of construction effected not only a saving in time, but also reduced the initial cost of the work as the cost of the watching and curing was probably more than the extra cost of the cement.

Construction.

Sub-Base.—In districts where a sandy or gravel soil was met with there was no particular treatment of the sub-base beyond the usual grading and rolling. Where clay was met with it was the usual practice to spread about 2 in. of sand after grading and consolidating with a roller. When that was done the sandy portion was thoroughly wetted over-night in order that when the concrete was deposited no water might be taken out of the base of the concrete by absorption. If that were to occur the bottom portion of the concrete would not be able to set properly, as insufficient water would remain in it for the complete crystallisation of the cement.

It was thought that it might be necessary to carry out this sand-spreading when the concrete was laid on a very hard sub-base.

Aggregate.—They were undoubtedly more strict on the subject of aggregate in the United States. The following were typical specifications:

State of Washington.

Fine Aggregate.—Graded from ¼ in. to 0·0058 in. diameter openings as follows:

	per cent.
Passing sieve having ¼-in. square openings between wires . .	100
Passing No. 28 sieve	17–37

Percentages were by weight in each case.

Coarse Aggregate.—The maximum size of the stone shall be 5 in., and graded as follows:

		per cent.
Passing a 3-in. round opening.	Not less than	98
,, 2-in. ,,	,,	82–95
,, 1-in. ,,	,,	37–55
,, ½-in. ,,	,,	15–23
,, ¼-in. square opening.	Not to exceed	5

Percentages were by weight in each case.

Pennsylvania.

Fine Aggregate.—Shall all pass a screen having circular openings ⅜ in. in diameter.

		per cent.
Passing No. 4 sieve.	Not less than	85
,, ,, 50 ,,	,, ,,	30
,, ,, 100 ,,	,, ,,	6

The above percentages were by weight.

It shall not contain more than 3 per cent. by weight of silt or other foreign substances.

Coarse Aggregate.

	per cent.
Passing 2¾-in. screen	100
,, 2½-in. ,, ...	95–100
,, 1¼-in. ,, ...	30–65
,, ⅝-in. ,, ...	0–15
,, ⅜-in. ,, ...	0–8

Wayne County, Michigan.

Fine Aggregate.

		per cent.
Passing ¼-in. screen		100
Retained on 20-mesh sieve	Not less than	20
Passing 20-mesh sieve	,,	40
,, 50 ,,	Not more than	20
,, 100 ,,	,,	6

Coarse Aggregate.

		per cent.
Passing 2½-in. screen		100
Retained on 2-in. screen . . .		2–10
Passing ½-in. screen	Not less than	10
,, ¼-in. ,,	Not more than	5

Coarse Aggregate for Wearing Course.

	per cent.
Passing 2-in. screen	100
Retained on 1¼-in. screen . . .	2–10
Passing ½-in. screen	5–15
„ ¼-in. „	0–3

There had been considerable discussion as to the best materials, and it was thought for some time that gravel did not give such good wearing qualities as stone. It was thought now, however, that the real cause of the bad wearing qualities was the fact that the pit ballast was supplied as won, and was, therefore, not properly graded and often contained too high a percentage of fine material. It seemed probable that, provided proper care were taken at the pit to grade the gravel in the same way as stone was graded, a satisfactory aggregate could be obtained. The material must still be viewed with suspicion if there were more than 5 per cent. of foreign substance in it and should only be accepted if it passed a satisfactory test when mixed with cement. For instance, the State of Pennsylvania insisted that the strength of mortar composed of one part by volume of Portland cement and three parts by volume of the sand at the age of seven and twenty-eight days should be not less than 75 per cent. that of the compressive strength of mortar made with cement and standard Ottawa sand.

In this country there seemed to be an advantage in using crushed gravel in the wearing course of a road, as the amount of aggregate to be washed could often be reduced to that used in the top course, and there was less chance of the exposed aggregate being splintered and removed by heavy steel-tyred lorries.

Slag was not entirely satisfactory on account of its large abrasion losses when used on a carriage surface, but where that material was cheaply obtained it might be accepted if the tests were satisfactory, at any rate for the bottom course, obtaining better aggregate for the top course.

Organisation.

The organisation on the contractors' side had reached a high pitch of efficiency. Labour-saving machines were used in the gravel pits or the quarries. The material arrived at the station properly graded and was raised into the hoppers by a grab. The hoppers had a measuring device at the bottom so that each lorry or light railway truck, as the case might be, received so many exact batches for the hoppers of the mixer. Each batch received its correct amount of cement, was run up to the mixer hopper, and shot in. There was thus no man-handling to speak of. The mixers were usually larger than those in this country, delivering 18 to 21 cubic feet of mixed concrete a batch. The mixer moved under its own power on caterpillar wheels, unless, for a matter of convenience, it was preferred to keep the mixer stationary and run the mixed concrete up to the position of depositing on a light railway.

It was found that by adopting these up-to-date methods it was quite an ordinary day's work to lay a length of 900 ft., 10 ft. wide and 8 in. deep, and although wages were higher in the United States than here as a result of this organisation the costs were only equal to or even lower than those for similar work in this country.

Cost.

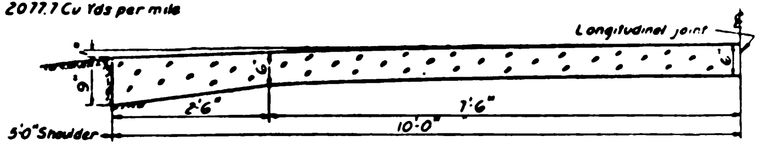
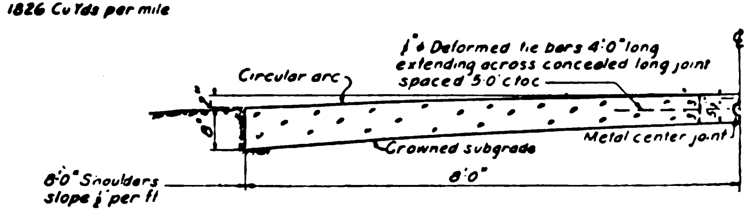
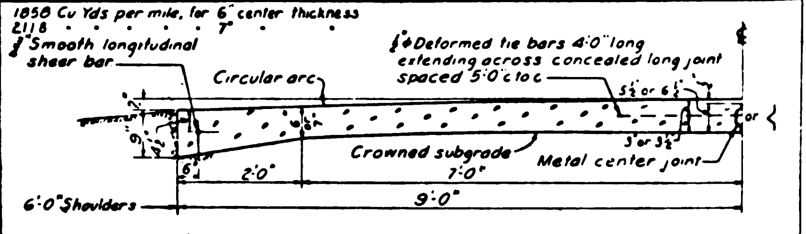
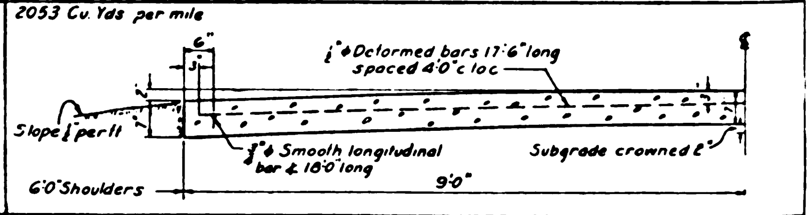
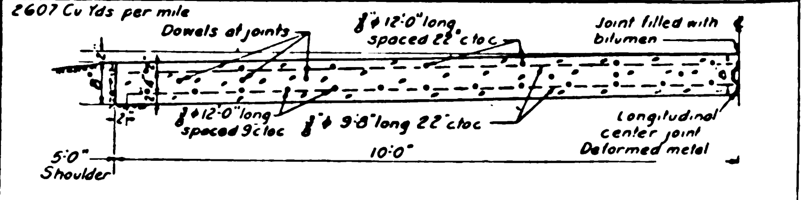
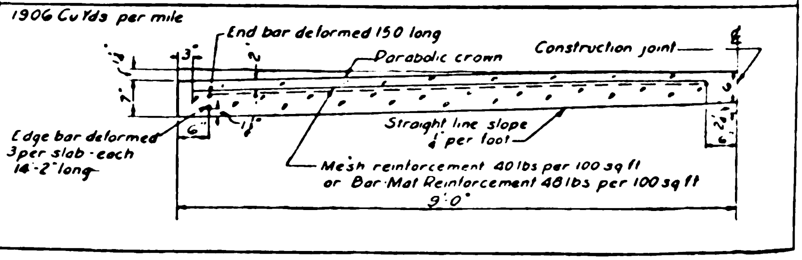
The cost of a concrete road between Croton and Reerskill in New York State including excavation was 14*s*. a square yard, of which 5*s*. 4*d*. was for excavation. This road was 8 in. thick and reinforced in the upper portion.

The cost of concrete roads (un-reinforced) in the State of Washington had not varied much during the past four years. The standard section was 6½ in. at the centre and 9 in. at the sides, and the cost in 1924 was 2·24 dols. per sq. yd. These figures included the cost of excavation.

Expansion Joints and Surfacing.

The tendency of construction to-day was undoubtedly in the direction of 10-ft. strips, which were satisfactory both from the point of view of the engineer and the contractor in the United States. By adopting this method it was possible to keep the traffic going whilst the road was being constructed. The dividing lines were excellent safety lines and assisted in reducing any tendency to crack.

Usually steel forms were employed. The reinforcement was placed in position and the concrete deposited, care being taken to slice the concrete against the sides of the form with the object of

STATE	TYPICAL CROSS-SECTIONS
CALIFORNIA	 2077.7 Cu Yds per mile Longitudinal joint ℄ 6" 9" 6" 2'6" 7'6" 10'0" 5'0" Shoulder
DELAWARE	 1826 Cu Yds per mile ½" ϕ Deformed tie bars 4'0" long extending across concealed long joint spaced 5'0" c to c Circular arc ℄ Metal center joint Crowned subgrade 8'0" 8'0" Shoulders slope ½" per ft
ILLINOIS	 1858 Cu Yds per mile, for 6" center thickness 2118 " " " " " 7" " " ⅝" Smooth longitudinal sheer bar Circular arc ½" ϕ Deformed tie bars 4'0" long extending across concealed long joint spaced 5'0" c to c ℄ 5½ or 6½ or 3" or 3½ Crowned subgrade Metal center joint 6" 2'0" 7'0" 9'0" 6'0" Shoulders
INDIANA	 2053 Cu. Yds per mile 6" 3" ½" ϕ Deformed bars 17'6" long spaced 4'0" c to c ℄ Slope ½" per ft ¾" ϕ Smooth longitudinal bar ℄ 18'0" long Subgrade crowned 2" 9'0" 6'0" Shoulders
NEW JERSEY	 2607 Cu Yds per mile Dowels at joints ⅝" ϕ 12'0" long spaced 22" c to c Joint filled with bitumen ℄ ⅝" ϕ 12'0" long spaced 9" c to c ⅝" ϕ 9'8" long 22" c to c Longitudinal center joint Deformed metal 2" 10'0" 5'0" Shoulder
NEW YORK	 1906 Cu Yds per mile End bar deformed 15'0" long 3" Parabolic crown Construction joint ℄ Edge bar deformed 3 per slab - each 14'-2" long 6" 1½" Straight line slope ¼" per foot Mesh reinforcement 40 lbs per 100 sq ft or Bar Mat Reinforcement 48 lbs per 100 sq ft 9'0"

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obtaining a close-knit face when the form was removed. The surface was tamped and then tested with a straight-edge, and any depressions filled in with the addition of a little fresh concrete, and finally tamped. The belt then followed.

According to theory just sufficient water should be used in the mixing to allow of the proper crystallisation of the cement, and this theory was very much preached in the United States. It had been found, however, that if strictly adhered to it was impossible to obtain a good running and close-knit surface. In consequence both engineers and contractors found it better to add sufficient water to produce a very slight scum on the surface. After this had been rubbed with the belt some of the scum still remained, and towards the end of the initial set the surface was sufficiently dry to broom off the scum in the form of crumbs. The sweeping was done directly across the road so that the lines of the bristles gave a pleasing appearance. The object of the sweeping was to prevent crazing, which undoubtedly took place in the United States if the precaution were not taken.

The rounding of the joints, transverse and longitudinal, was done with a very simple tool rounded to the necessary radius. The tool was 3 to 4 in. wide, with one edge rounded, and the result of its use was that one saw on a completed road a narrow smooth line running each side of the joint whilst the remainder of the surface was slightly roughened by the brooming; the whole giving a very good appearance.

Another advantage of using the smoothing tool was that when tamping the concrete of the second or further longitudinal strips the 4 in. of smooth surface gave an excellent seat for the tamper, which was used on that on one side and the steel or wooden forms on the other. There was thus less risk of the surfaces being at different levels.

It was often noticeable in this country, when the tool was not used and the roads were constructed in two or more longitudinal slabs, that owing to the concrete surface being rougher than the form and the peaks of these rough edges being above the proper finished surface level, there was a great tendency for the second strip to be at a slightly higher level than the first level at the point where they adjoined.

Pre-moulded bituminous expansion joint material was very common, and, if that were used, it was important that there should be enough filler in the bitumen to prevent any risk of brittleness at freezing temperatures. The width of the pre-moulded filler might be equal to the depth of the pavement, or it might be slightly wider.

Another method was to put some material such as corrugated paper in the position where the joint was to be, and remove this at a later period and run a filler into the joint. One specification for such a filler was as follows:—

The material to be heated as required for proper thinning, but not in excess of 350 degrees F. This material shall be of an asphalte of 85 to 100 penetration.

	Min.	Max.
Penetration at 25 degs. C. 100 grs. 5 sec.	80	100
Ductility at 25 degs. C. cm. .	30	—
Inorganic insoluble in CS_2 per cent. by weight	15	26
Evaporation loss per cent. by weight 50 grs., 5 hrs., 163 C. .	—	2

Some difficulty had been previously experienced in the United States in fixing the pre-moulded filler in position when the expansion joints occurred during the day's work, and not merely at the dinner hour or at the end of the day's work. A very simple method of overcoming this trouble was now extensively adopted. A steel plate with the bottom edge cut away into a series of fairly large gaps was fixed across the road by means of stakes, and the filler clipped to it. The concrete was then deposited against the filler, and also against the plate. Where the gaps existed in the plate the filler was thus supported by concrete on both sides, and when the plate was removed there was sufficient friction between the concrete and the filler to hold the latter in place. On removal of the plate, which was only about ¼ in. thick, the concrete was rammed against the filler to fill the vacant space. The stakes could be of iron with an eye at the top to ensure their easy removal after use.

In this country the concrete road could be considered to be in its infancy compared with the position in the United States, where some 37,000 miles had been constructed.

Standard Specification for Reinforced Concrete.

We give herewith further abstracts from the Standard Specification for Reinforced Concrete which has been prepared by the leading engineering institutions in the United States and published by the American Society for Testing Materials. The first part of this Specification, dealing with materials and construction, was given in our December issue, and the second part, dealing with design, is now given.

Design.

General Assumptions.

103. The design of reinforced concrete members under these specifications shall be based on the following assumptions:

(*a*) Calculations are made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

(*b*) A plane section before bending remains plane after bending, shearing distortions being neglected.

(*c*) The modulus of elasticity of concrete in compression is constant within the limits of working stresses and the distribution of compressive stress in beams is rectilinear.

(*d*) The moduli of elasticity of concrete in computations for the position of the neutral axis, for the resisting moment of beams, and for compression of concrete in columns, are as follows:

(1) $\frac{1}{15}$ that of steel when the compressive strength of the concrete at 28 days exceeds 1,500 and does not exceed 2,200 lbs. per sq. in.;

(2) $\frac{1}{12}$ that of steel when the compressive strength of the concrete at 28 days exceeds 2,200 and does not exceed 2,900 lbs. per sq. in.;

(3) $\frac{1}{10}$ that of steel when the compressive strength of the concrete at 28 days is greater than 2,900 lbs. per sq. in.

(*e*) In calculating the moment of resistance of reinforced concrete beams and slabs the tensile resistance of the concrete is neglected.

(*f*) The bond between the concrete and the reinforcement remains unbroken throughout the range of working stresses. Under compression the two materials are therefore stressed in proportion of their moduli of elasticity.

(*g*) Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns. Formula 43 for the permissible compressive stress in reinforced concrete columns takes into account the effect of shrinkage in the concrete on the stress in the longitudinal reinforcement. It is not required, however, that the designer consider shrinkage stresses in columns, except through the use of that formula.

Flexure of Rectangular Reinforced Concrete Beams and Slabs.

104. Computations of flexure in rectangular reinforced concrete beams and slabs shall be based on the following formulas:

Reinforced for Tension only.

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn \quad . \quad . \quad (1)$$

Arm * of resisting couple,

$$j = 1 - \frac{k}{3} \quad . \quad . \quad . \quad . \quad (2)$$

Compressive unit stress * in extreme fibre of concrete,

$$f_c = \frac{2M}{jkbd^2} = \frac{2pf_s}{k} \quad . \quad . \quad . \quad (3)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} = \frac{M}{pjbd^2} \quad . \quad . \quad (4)$$

Steel ratio for balanced reinforcement,

$$p = \frac{1}{2} \frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nf_c} + 1\right)} \quad . \quad . \quad . \quad (5)$$

---

* For f_s = 16,000 to 18,000 lbs. per sq. in. and f_c = 800 to 900 lbs. per sq. in., j may be assumed as 0·86. For values of pn varying from 0·04 to 0·24, jk is approximately equal to 0·67 $\sqrt{pn}$.

Reinforced for both Tension and Compression.

Position of neutral axis,

$$k = \sqrt{2n\left(p + p'\frac{d'}{d}\right) + n^2(p + p')^2} - n(p + p') \quad . \quad . \quad . \quad . \quad (6)$$

Position of resultant compression,

$$z = \frac{\frac{1}{3}k^3d + 2p'nd'\left(k - \frac{d'}{d}\right)}{k^2 + 2p'n\left(k - \frac{d'}{d}\right)} \quad . \quad (7)$$

Arm of resisting couple,

$$jd = d - z \quad . \quad . \quad . \quad . \quad (8)$$

Compressive unit stress in extreme fibre of concrete,

$$f_c = \frac{6M}{bd^2\left[3k - k^2 + \frac{6p'n}{k}\left(k - \frac{d'}{d}\right)\left(1 - \frac{d'}{d}\right)\right]} \quad . \quad . \quad . \quad . \quad (9)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{pjbd^2} = nf_c\frac{1 - k}{k} \quad . \quad . \quad (10)$$

Compressive unit stress in longitudinal reinforcement,

$$f'_s = nf_c\frac{k - \frac{d'}{d}}{k} \quad . \quad . \quad . \quad (11)$$

105. The symbols used in Formulas 1 to 23 are defined as follows:

A_s = effective cross-sectional area of metal reinforcement in tension in beams;

b = width of rectangular beam or width of flange of **T**-beam;

d = depth from compression surface of beam or slab to centre of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to centre of compression reinforcement;

f_c = compressive unit stress in extreme fibre of concrete;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth d;

k = ratio of depth of neutral axis to depth d;

l = span length of beam or slab (generally distance from centre to centre of supports—see Section 106);

M = bending moment or moment of resistance in general;

n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams = A_s/bd;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

w = uniformly distributed load per unit of length of beam or slab;

z = depth from compression surface of beam or slab of resultant of compressive stresses.

106. The span length l of freely supported beams and slabs shall be the distance between centres of the supports, but shall not exceed the clear span plus the depth of beam or slab. The span length for continuous or restrained beams built to act integrally with supports shall be the clear distance between faces of supports. Where brackets having a width not less than the width of the beam and making an angle of 45 degrees or more with the horizontal axis of a restrained beam are built to act integrally with the beam and support, the span shall be measured from the section where the combined depth of the beam and bracket is at least one-third more than the depth of the beam, but no portion of such a bracket shall be considered as adding to the effective depth of the beam. Maximum negative moments are to be considered as existing at the ends of the span, as defined above.

107. Beams and slabs of equal spans built to act integrally with beams, girders, or other slightly restraining supports and carrying uniformly distributed loads shall be designed for the following moments at critical sections:

(*a*) Beams and slabs of one span,

Maximum positive moment near centre,

$$M = \frac{wl^2}{8} \quad . \quad . \quad . \quad (12)$$

(*b*) Beams and slabs continuous for two spans only,

(1) Maximum positive moment near centre,

$$M = \frac{wl^2}{10} \qquad \ldots \qquad (13)$$

(2) Negative moment over interior support,

$$M = \frac{wl^2}{8} \qquad \ldots \qquad (14)$$

(*c*) Beams and slabs continuous for more than two spans,

(1) Maximum positive moment near centre and negative moment at support of interior spans,

$$M = \frac{wl^2}{12} \qquad \ldots \qquad (15)$$

(2) Maximum positive moment near centres of end spans and negative moment at first interior support,

$$M = \frac{wl^2}{10} \qquad \ldots \qquad (16)$$

(*d*) Negative moment at end supports for cases (*a*), (*b*), (*c*) of this section,

$$M = \text{not less than } \frac{wl^2}{16} \qquad \ldots \qquad (16a)$$

108. Beams and slabs built into brick or masonry walls in a manner which develops partial end restraint shall be designed for a negative moment at the support of

$$M = \text{not less than } \frac{wl^2}{16} \qquad \ldots \qquad (17)$$

109. Beams and slabs of equal spans freely supported and assumed to carry uniformly distributed loads shall be designed for the moments specified in Section 107, except that no reinforcement for negative moment need be provided at end supports where effective measures are taken to prevent end restraint. The span shall be taken as defined in Section 106 for freely supported beams.

110. Beams and slabs of equal span built to act integrally with columns, walls, or other restraining supports and assumed to carry uniformly distributed loads, shall (except as provided in Section 107) be designed for the following moments at critical sections:

(*a*) Interior spans,

(1) Negative moment at interior supports except the first,

$$M = \frac{wl^2}{12} \qquad \ldots \qquad (18)$$

(2) Maximum positive moment near centres of interior spans,

$$M = \frac{wl^2}{16} \qquad \ldots \qquad (19)$$

(*b*) End spans of continuous beams and beams of one span in which I/l is less than twice the sum of the values of I/h for the exterior columns above and below which are built into the beams:

(1) Maximum positive moment near centre of span and negative moment at first interior supports,

$$M = \frac{wl^2}{12} \qquad \ldots \qquad (20)$$

(2) Negative moment at exterior supports,

$$M = \frac{wl^2}{12} \qquad \ldots \qquad (21)$$

(*c*) End spans of continuous beams, and beams of one span, in which I/l is equal to or greater than twice the sum of the values of I/h for the exterior column above and below which are built into the beams:

(1) Maximum positive moment near centre of span and negative moment at first interior support,

$$M = \frac{wl^2}{10} \qquad \ldots \qquad (22)$$

(2) Negative moment at exterior support,

$$M = \frac{wl^2}{16} \qquad \ldots \qquad (23)$$

111. Continuous beams with unequal spans, or with other than uniformly distributed loading, whether freely-supported or restrained, shall be designed for the actual moments under the conditions of loading and restraint. Provision shall be made where necessary for negative moment near the centre of short spans which are adjacent to long spans, and for the negative moment at the end supports if restrained.

112. The distance between lateral supports of the compression area of a beam shall not exceed 24 times the least width of compression flange.

Flexure of Reinforced Concrete T-Beams.

113. Computations of flexure in reinforced concrete **T**-beams shall be based on the following formulas:

(*a*) *Neutral Axis in the Flange.*—Use formulas for rectangular beams and slabs in Section 104.

(*b*) *Neutral Axis below the Flange.*—Position of neutral axis,

$$kd = \frac{2ndA_s + bt^2}{2nA_s + 2bt} \quad . \quad . \quad . \quad (24)$$

Position of resultant compression,

$$z = \left(\frac{3kd - 2t}{2kd - t}\right)\frac{t}{3} \quad . \quad . \quad (25)$$

Arm of resisting couple,

$$jd = d - z \quad . \quad . \quad . \quad (26)$$

Compressive unit stress in extreme fibre of concrete,

$$f_c = \frac{Mkd}{bt(kd - \frac{1}{2}t)jd} = \frac{f_s}{n}\left(\frac{k}{1 - k}\right) \quad (27)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \quad . \quad . \quad . \quad (28)$$

Formulas 24, 25, 26, 27 and 28 neglect compression in the stem.

114. The symbols used in Formulas 24 to 28 are defined in Section 105, except as follows: b' = width of stem of **T**-beam; t = thickness of flange of **T**-beam.

115. Effective and adequate bond and shear resistance shall be provided in beam-and-slab construction at the junction of the beam and slab; the slab shall be built and considered an integral part of the beam; the effective flange width to be used in the design of symmetrical **T**-beams shall not exceed one-fourth of the span length of the beam, and its overhanging width on either side of the web shall not exceed eight times the thickness of the slab nor one-half the clear distance to the next beam. For beams having a flange on one side only, the effective flange width to be used in design shall not exceed one-tenth of the span length of the beam, and its overhanging width from the face of the web shall not exceed six times the thickness of the slab nor one-half the clear distance to the next beam.

116. Where the principal slab reinforcement is parallel to the beam, transverse reinforcement, not less in amount than 0·3 per cent. of the sectional area of the slab, shall be provided in the top of the slab and shall extend across the beam and into the slab not less than two-thirds of the width of the effective flange overhang. The spacing of the bars shall not exceed 18 in.

117. Provision shall be made for the compressive stress at the support in continuous **T**-beam construction.

118. The flange of the beam shall not be considered as effective in computing the shear and diagonal tension resistance of **T**-beams.

119. Isolated beams in which the **T**-form is used only for the purpose of providing additional compression area shall have a flange thickness not less than one-half the width of the web and a total flange width not more than 4 times the web thickness.

Diagonal Tension and Shear.

120. The symbols used in Formulas 29 to 35 are defined in Section 105, except as follows:

A_v = total area of web reinforcement in tension within a distance s, that is s_1, s_2, s_3, ... s_n, or the total area of all bars bent up in any one plane;

a = angle between web bars and longitudinal bars;

F = total tension in a bar;

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with standard methods;

f_v = tensile unit stress in web reinforcement;

Q = ratio of the average to the maximum bond stress computed by Formula 34 within the distance y;

Σo = sum of perimeters of bars in one set;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips ;

s = spacing of web bars or stirrups measured at the plane of the lower reinforcement and in the direction of the longitudinal axis of the beam ;

t_1 = thickness of flat slab without dropped panels or thickness of a dropped panel ;

t_2 = thickness of flat slab with dropped panels at points away from the dropped panel ;

u = bond stress per unit of area of surface of bar ;

v = shearing unit stress ;

V = total shear ;

x = length of bar added for anchorage, including the hook, if any ;

y = distance from the point at which tension is computed to the point of beginning of anchorage.

121. The shearing unit-stress, v, in reinforced concrete beams shall be taken as not less than that computed by Formula 29.

$$v = \frac{V}{bjd} \quad . \quad . \quad . \quad . \quad (29)$$

122. For purpose of design of beams carrying uniform loads, not less than one-fourth of the total shearing resistance required at either end of span shall be provided at the section where the computed shearing stress is zero ; from that section to the ends of span the required shearing resistance shall be assumed to vary uniformly.

123. The shearing unit stress shall be computed on the minimum width of rectangular beams and on the minimum thickness of the web in beams of **I** or **T**-section.

124. The width of the effective section for shear as governing diagonal tension shall be assumed as the thickness of the concrete web plus one-half the thickness of the vertical webs of the concrete or clay tile in contact with the beam.

125. Web reinforcement may consist of : (*a*) Vertical stirrups or web reinforcing bars ; (*b*) Inclined stirrups or web reinforcing bars forming an angle of 30 deg. or more with the longitudinal bars ; (*c*) Longitudinal bars bent up at an angle of 15 deg. or more with the direction of the longitudinal bars. Stirrups or bent-up bars which are not anchored at both ends, according to the provisions of Section 141, shall not be considered effective as web reinforcement. When the shearing stress is not greater than $0{\cdot}06\,f'_c$, the distance s measured in the direction of the axis of the beam between two successive stirrups, or between two successive points of bending up of bars, or from the point of bending up of a bar to the edge of the support, shall not be greater than

$$s = \frac{45d}{a + 10} \quad . \quad . \quad . \quad (30)$$

where the angle a is in degrees. When the shearing stress is greater than $0{\cdot}06f'_c$, the distance s shall not be greater than two-thirds of the values given by Formula 30.

127. The shearing unit stress computed by Formula 29 in beams in which the longitudinal reinforcement is without special anchorage shall not exceed the values given by Formulas 31 and 32 and in no case shall it exceed $0{\cdot}06f'_c$.

When a is between 45 and 90 deg.,

$$v = 0{\cdot}02f'_c + \frac{f_vA_v}{bs \sin a} \quad . \quad . \quad (31)$$

When a is less than 45 deg.,

$$v = 0{\cdot}02f'_c + \frac{f_vA_v}{bs}(\sin a + \cos a) \quad (32)$$

128. The shearing unit stress computed by Formula 29 in beams in which longitudinal reinforcement is anchored by means of hooked ends or otherwise, as specified in Section 140, shall not exceed the value given by Formulas 31 and 32, when $0{\cdot}03f'_c$ is substituted for $0{\cdot}02f'_c$ in those formulas ; in no case shall the shearing unit stress exceed $0{\cdot}12f'_c$.

129. Where the web reinforcement consists of bars bent up at a single point, the point of bending shall be at a distance s from the edge of the support not greater than that given in Section 125 and the value of the quantity $\frac{f_vA_v}{bs}$ $(\sin a + \cos a)$ used in the design shall not exceed 75 lbs. per sq. in.

130. Where two or more types of web reinforcement are used in conjunction the total shearing resistance of the beam shall be assumed as the sum of the shearing resistances computed for the various types separately. In such computations the shearing resistance of the concrete

(the term $0{\cdot}02f'_c$ or $0{\cdot}03f'_c$ in Formulas 31 and 32) shall be included only once. In no case shall the maximum shearing stresses be greater than the limiting values given in Sections 127 and 128.

131. The shearing unit stress in flat slabs shall not exceed the value of v as given by Formula 33,

$$v = 0{\cdot}02\, f'_c\,(1 + r) \quad . \quad . \quad (33)$$

and shall not in any case exceed $0{\cdot}03f'_c$. The shearing unit stress shall be computed on: (*a*) A vertical section which has a depth in inches of $\frac{7}{8}\,(t_1 - 1\frac{1}{2})$ and which lies at a distance in inches of $t_1 - 1\frac{1}{2}$ from the edge of the column capital; and (*b*) A vertical section which has a depth in inches of $\frac{7}{8}\,(t_2 - 1\frac{1}{2})$ and which lies at a distance in inches of $t_2 - 1\frac{1}{2}$ from the edge of the dropped panel. In no case shall r be less than 0·25. Where the shearing stress computed as in (*a*) is being considered, r shall be assumed as the proportional amount of the negative reinforcement, within the column strip, crossing the column capital. Where the shearing stress computed as in (*b*) is being considered, r shall be assumed as the proportional amount of negative reinforcement, within the column strip, crossing entirely over the dropped panel. In special cases, where supported by satisfactory engineering analysis, diagonal tension reinforcement may be used and increased shearing stresses allowed in accordance with Sections 127 to 130.

132. The shearing stress shall be taken as not less than that computed by Formula 29. The stress on the critical section shall not exceed $0{\cdot}02f'_c$ for footings with straight reinforcement bars, nor $0{\cdot}03f'_c$ for footings in which the reinforcement bars are anchored at both ends by adequate hooks or otherwise as specified in Section 140.

133. The critical section for diagonal tension in footings on soil shall be computed on a vertical section through the perimeter of the lower base of a frustum of a cone or pyramid which has a base angle of 45 deg., and which has for its top the base of the column or pedestal and for its lower base the plane at the centroid of longitudinal reinforcement.

134. The critical section for diagonal tension in footings on piles shall be computed on a vertical section at the inner edge of the first row of piles entirely outside a section midway between the face of the column or pedestal and the section described in Section 133 for soil footings, but in no case outside of the section described in Section 133. The critical section for piles not arranged in rows shall be taken midway between the face of the column and the perimeter of the base of the frustum described in Section 133.

Bond and Anchorage.

135. Where bar reinforcement is used to resist tensile stresses developed by beam action, the bond stress shall be taken as not less than that computed by Formula 34,

$$u = \frac{V}{\Sigma ojd} \quad . \quad . \quad . \quad (34)$$

For continuous or restrained members, the critical section for bond for the positive reinforcement shall be assumed to be at the point of inflection; that for the negative reinforcement shall be assumed to be at the face of the support, and at the point of inflection. For simple beams or freely supported end spans of continuous beams, the critical section for bond shall be assumed to be at the face of the support. Bent-up longitudinal bars which, at the critical section, are within a distance $\frac{d}{3}$ from horizontal reinforcement under consideration, may be included with the straight bars in computing Σo. In footings only the bars specified in Section 177 as effective in resisting bending moment shall be considered as resisting bond stresses. Special investigation shall be made of bond stresses in footings with stepped or sloping upper surface, as maximum bond stresses may occur at the vertical plane of the steps or near the edges of the footing.

136. In beams where the ordinary anchorage described in Section 139 is provided, the bond stress computed by Formula 34 at any section shall not exceed the following values:

For plain bars . . . $u = 0{\cdot}04f'_c$
For deformed bars meeting the requirements of Section 23 . . . . . $u = 0{\cdot}05f'_c$

137. In beams where special anchorage of the bars is provided as specified in Section 140, bond stresses exceeding those specified in Section 136 may be

used, provided the total tensile stress at a point of abrupt change in stress, or at the point of maximum stress, does not exceed the value of F given by Formula 35.

$$F = Qu\Sigma oy + u\Sigma ox \quad . \quad . \quad (35)$$

where F = total tension in the bar;
Σo = the perimeter of the bar under consideration;
Q = ratio of the average to the maximum bond stress computed by Formula 34 within the distance y;
u = permissible bond stress = $0{\cdot}04f'_c$ for plain and $0{\cdot}05f'_c$ for deformed bars meeting the requirements of Section 23;
x = the length of bar added for anchorage, including the hook, if any;
y = distance from the point at which the tension is computed to the point of beginning of anchorage.

The length of bar added for anchorage may be either straight or bent. The radius of bend shall not be less than four bar diameters.

138. The permissible bond stress for footings and similar members in which reinforcement is placed in more than one direction shall not exceed 75 per cent. of the values in Sections 136 and 137.

139. In continuous, restrained, or cantilever beams, anchorage of the tensile negative reinforcement beyond the face of the support shall provide for the full maximum tension with bond stresses not greater than those specified in Section 136. Such anchorage shall provide a length of bar not less than the depth of the beam. In the case of end supports which have a width less than three-fourths of the depth of the beam, the bars shall be bent down toward the support a distance not less than the effective depth of the beam. The portion of the bar so bent down shall be as near to the end of the beam as protective covering permits. In continuous or restrained beams, negative reinforcement shall be carried to or beyond the point of inflection. Not less than one-fourth of the area of the positive reinforcement shall extend into the support to provide an embedment of ten or more bar diameters. In simple beams or freely-supported end spans of continuous beams at least one-fourth of the area of the tensile reinforcement shall extend along the tension side of the beam and beyond the face of the support to give an embedment of ten or more bar diameters.

140. Where increased shearing stresses are used as provided in Sections 128 and 132, or increased bond stresses as provided in Section 137, special anchorage of all reinforcement in addition to that required in Section 139 shall be provided:

(*a*) In continuous and restrained beams, anchorage beyond points of inflection of one-third the area of the negative reinforcement and beyond the face of the support of one-third the area of the positive reinforcement shall be provided to develop one-third of the maximum working stress in tension, with bond stresses not greater than those specified in Section 136.

(*b*) At the edges of footings anchorage for all the bars for one-third the maximum working stress in tension shall be provided within a region where the tension in the concrete, computed as an unreinforced beam, does not exceed 40 lbs. per sq. in.

(*c*) In simple beams or freely-supported end spans of continuous beams, at least one-half of the tensile reinforcement shall extend along the tension side of the beam to provide an anchorage beyond the face of the support for one-third of the maximum working stress in tension.

141. Web bars shall be anchored at both ends by: (*a*) providing continuity with the longitudinal reinforcement; or (*b*) bending around the longitudinal bar; or (*c*) a semi-circular hook which has a radius not less than four times the diameter of the web bar. Stirrup anchorage shall be so provided in the compression and tension regions of a beam as to permit the development of safe working tensile stress in the stirrup at a point $0{\cdot}3d$ from either face. Generally a properly-anchored stirrup whose diameter does not exceed $\frac{1}{50}$ of the depth of the beam will meet these requirements. The end anchorage of a web member not in bearing on the longitudinal reinforcement shall be such as to engage an amount of concrete sufficient to prevent the bar from pulling out. The stirrups shall be as close to the surfaces as fireproofing requirements permit.

(*To be concluded.*)

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

Reinforcement.

Question.—I should be glad if you would be kind enough to advise me with regard to the following :—Splitting and tailing of round mild steel rods ; (*a*) Depth of split in relation to diameter of rod ; (*b*) Radius, in relation to diameter, to which each half of tail should be bent ; (*c*) Usual method of splitting ?—G. A. S.

Answer.—The depth of the split is generally made about six times the diameter of the rod and is generally done in a shearing machine, one-half being sheared to an angle of 30 deg. from the axis of the bar while the other half is sheared to an angle of 30 deg. from the axis of the bar in the other direction. Sometimes these angles are as little as 20 deg. If done in this manner the cost is very low. Unfortunately the fish-hook then exposes cutting edges to the concrete, and a very much stronger result is obtained by hack-sawing down the centre of the rod for a length of six diameters and then wedging the two edges apart, but this method is much more expensive. —O. F.

Laying Concrete Under Water.

Question.—What is the best method of laying concrete in still water, such as block foundations in water-logged ground ? Is concrete laid in this way and composed of ordinary concrete, inferior to concrete laid above ground ? —W. F. P.

Answer.—As a rule the best method of laying concrete in still water is to lower it to the bottom in a hopper having a hinged bottom which can be released when the hopper rests on the ground, so that when the hopper is raised the concrete is gently deposited without passing through the water. Concrete laid in this way is very slightly inferior in strength to concrete placed above the ground.

Concrete Casing to a Steel Stanchion.

Question.—A steel stanchion 12 ft. high is proposed to be surrounded with concrete without first encasing it in lathing—is there any fear of cracking or falling away if this method is adopted? —J. S.

Answer.—Concrete casing around a steel stanchion without any horizontal reinforcement or wrapping is certainly liable to crack at the corners and to come away. Even if the wrapping consisted of a spiral of wire of 3-in. pitch it would help to prevent this concrete getting loose.

Reservoirs.

Question.—What is the practice in England about the amount of working stress allowed on steel used for reinforcement in reservoirs ? As in a reservoir minute cracks, however small, are very undesirable, as besides promoting leakage they might cause the reinforcement to rust, it appears that the stress allowed on the steel should not exceed 5,000 lbs. per sq. in. Now this is under one-third of the working stress commonly allowed on the steel for reinforced concrete structures other than reservoirs, viz. 16,000 lbs. Moreover, it appears that on the Continent tensile stress on the concrete is often allowed in such structures as water tanks, and in such cases the working stress on the steel is determined on the criterion that the strains on the two materials are equal.

$$\frac{\text{Stress on steel}}{\text{Strain}} = \frac{\text{Stress concrete to tension.}}{\text{Same strain as in steel.}}$$

This is analogous to English practice in regard to reinforcing in compression. In such cases the working stress on the steel is taken at 15 times that of the concrete.

What is the modular ratio for both materials in tension ? Is it also 15 ?

The ultimate stress in tension on concrete is generally regarded as one-tenth of the compression; the modulus of elasticity for concrete in tension should be smaller than for that in compression; following this reasoning, the modular ratio for both materials in tension should be higher than 15.

In Continental textbooks the modular ratio is varied for rich concrete, and is given as high as 35, with a tensile stress in the concrete of as much as 284 lbs. per sq. in. This would give working stress for steel 35 × 284 = 9,940 lbs. per sq. in., and not 5,000 lbs. Rich concrete is taken to be a mixture in the proportion of about 1 : 1·2 : 2·4.—L. G.

Answer.—To make a reservoir watertight it is necessary first of all to use a watertight concrete, and it is not advisable to have this less rich than is given by the proportions 1 : 1½ : 3. To prevent cracks in the concrete it is necessary not only to keep the steel stress so proportioned that it will not exceed, say, 10,000 lbs. per sq. in. when this takes the whole stress, but it is also necessary to see that the tensile stress in the concrete does not exceed about 150 lbs. per sq. in. when the steel is either ignored, or, more accurately, replaced by fifteen times its area of concrete.

For the purposes of this calculation the modular ratio may with sufficient accuracy be taken as fifteen. Our correspondent is not correct in saying that because the ultimate stress in tension is about one-tenth of the compression the modulus of elasticity in tension should therefore be smaller than for that in compression. There is, in fact, no connection between the ultimate stress and the modulus of elasticity. The modular ratio for rich concretes is certainly less than that for poor concretes, because the coefficient of elasticity of a strong concrete is always greater than that of a weak concrete, and it would therefore be quite ridiculous to use as high a figure as 35 for a rich concrete.—O. F.

Stone-Dust in Concrete.

Question.—I note in your issue for December, a statement that the use of stone-dust is always dangerous. I presume that what is here referred to is the danger that the dust might not be "stone" dust, but consist of fine particles of clay or other foreign matter from the quarry, which would be deleterious to concrete.

From tests I have made recently the addition of sufficient *stone*-dust to fill the voids in the sand had the effect of increasing the tensile test of 3 to 1 briquettes at 7 and 28 days to such an extent as to suggest the advisability in the interests of economy of adopting this method of proportioning concrete, seeing that the price of stone-dust is approximately half that of sand.

In addition to the saving in cost, a denser and stronger concrete is procured, especially if care be taken that the amount of sand is enough to occupy fully the voids in the stone and the dust those in the sand. I shall be glad to have your view on this point.—W. Y. C.

Answer.—When we said that the use of stone-dust is always dangerous we did not imply that it cannot sometimes be used with advantage, but that unless tests have been made with the particular stone-dust in question in relation to the other ingredients with which it is to be mixed we cannot ensure that the result of introducing stone-dust may not be very deleterious. It depends so greatly on the exact nature of the stone-dust, which may consist to a large extent of clay and other foreign matter which in the process of crushing of the stone always find their way into the dust. As in the particular case quoted the stone-dust seems to have been shown to have produced a definitely advantageous result, there would, of course, be no objection to continuing its use.

We would, however, suggest that if the concrete is to be reinforced tests of porosity should also be made, since many stones are of a porous nature and the introduction of dust from such stones might increase the porosity of the concrete and so render the concrete less able to protect the steel from corrosion. The difficulty, of course, is in the use of the word "stone," which covers materials differing so widely from one another that some will be satisfactory while others will be quite unsatisfactory.—O. F.

Prospective New Concrete Work.

Ardsley.—*Houses.*—The U.D.C. has applied for sanction to a loan of £23,000 for the erection of 34 houses.

Aylesbury.—*Houses.*—The R.D.C. proposes to build 100 houses.

Bacup.—*Houses.*—A scheme for the construction of 100 houses is being considered by the Housing Committee.

Beckenham.—*Houses.*—The U.D.C. proposes to erect 60 houses at a cost of £30,000.

Bentley.—*Bridge.*—A proposal is being considered for the construction of a bridge at Bentley.

Bexhill.—*Bridge.*—The T.C. has applied for a loan of £8,051 for the construction of a bridge across the railway at Manor Road.

Blackpool.—*Road.*—The T.C. proposes to construct a 60-ft. road from Preston New Road.

Bolton.—*Houses.*—The Corporation Housing Committee has applied for sanction to build 182 houses.

Bournemouth.—*Concrete Groyne.*—The Corporation proposes to construct a concrete groyne.

Bournemouth.—*Promenade.*—A sum of £56,000 is to be spent on extending the Undercliff Promenade.

Bradford.—*Road.*—The T.C. proposes to construct a by-pass road at Wyke. The cost is estimated at £50,000.

Bristol.—*Houses.*—The Corporation has applied for sanction to a loan of £39,000 for housing purposes.

Bristol.—*Tanks.*—The Corporation has applied for sanction to a loan of £4,479 for the provision of water storage tanks at Ham Green Hospital.

Congresbury—*Road.*—The Somerset C.C. has applied for sanction to a loan towards the construction of a by-pass road to the west of the existing main road at Congresbury.

Darlaston.—*Houses.*—The U.D.C. is seeking permission to borrow £28,564 for housing purposes.

Doncaster.—*Houses.*—The Corporation proposes to erect 160 houses.

Dover.—*Sea Wall.*—The Southern Railway proposes to erect a sea wall at Western Beach.

Evesham.—*Bridge.*—The Worcestershire C.C. has applied for a grant of £9,176 for the construction of a bridge over the Avon.

Frinton.—*Piles.*—The U.D.C. proposes to spend £1,190 on the construction of concrete piles to replace the existing groynes.

Glasgow.—*Bridge.*—A sub-committee has been appointed to inquire into a proposal to erect a bridge over the Clyde at Dixon Street.

Gloucester.—*Houses.*—The City Council has applied for a loan of £31,500 for the erection of 68 houses.

Great Yarmouth.—*Sea Wall.*—The Corporation proposes to spend £73,000 on the construction of a sea wall and promenade.

Grindleton.—*Bridge.*—A scheme is being considered by the C.C. for the erection of a bridge at Grindleton.

Hastings.—*Reservoir.*—The Corporation proposes to construct a reservoir, estimated to cost £36,800.

Hedley.—*Bridge.*—The Lanchester R.D.C. has instructed the Surveyor to prepare plans for the erection of a bridge over Hedley Hope new road.

Horsforth.—*Houses.*—The U.D.C. has applied for sanction to a loan of £47,100 for the erection of 100 houses.

Hull.—*Houses.*—The Corporation's housing scheme includes the erection of 500 houses.

Humbie.—*Bridge.*—A reinforced concrete bridge is to be erected at the Birne Water ford. The cost is estimated at £230.

Liskeard.—*Houses.*—The Housing Committee is inquiring into a scheme for the erection of 100 houses.

Liverpool.—*Houses.*—The Corporation has acquired 460 acres at Morris Green as a site for the erection of 5,520 houses.

Llandilo.—*Road.*—A road is to be constructed through Llandilo at a cost of £30,000.

Londonderry.—*Dam.*—The Corporation proposes to erect a concrete dam, 120 ft. high, on the Altnaheglish river, to form a reservoir with a capacity of 500 million gallons.

Loughborough.—*Houses.*—The Corporation proposes to erect 100 houses.

Northwich.—*Houses.*—The R.D.C. has applied for sanction to a loan of £18,694 for housing purposes.

Nottingham.—*Grand Stand.*—The Notts. County Cricket Club proposes to spend £5,000 on the construction of two reinforced concrete stands.

NOTTINGHAM.—*Roads.*—The Corporation proposes to construct roads to connect the Colwick estate with Sneinton Dale, Sneinton Boulevard, and Parkdale Road.

OXFORD.—*Concrete Houses.*—The T.C. proposes to erect a further number of concrete houses.

PENRITH.—*Houses.*—The R.D.C. proposes to build 50 houses.

RETFORD.—*Houses.*—The T.C. has applied for a loan of £19,075 for building purposes.

SCARBOROUGH.—*Concrete Road.*—The T.C. proposes to construct a reinforced concrete road from Londesborough Road to Avenue Road.

SIDMOUTH.—*Houses.*—The U.D.C. has applied for sanction to a loan of £41,965 for the erection of 70 houses.

SOLIHULL.—*Houses.*—The U.D.C. has applied for sanction to erect 100 houses.

SWANAGE.—*Groynes.*—The U.D.C. has applied for permission to construct two groynes on the beach.

TORQUAY.—*Embankment.*—The T.C. proposes to replace the existing embankment with a reinforced concrete structure.

TORQUAY.—*Houses.*—The T.C. proposes to erect 100 houses at Barton.

TYNEMOUTH.—*Road.*—A road is to be constructed, at a cost of £3,900, to connect Lansdown Terrace with Albion Road.

UXBRIDGE.—*Reservoir.*—The U.D.C. has applied for a grant of £7,000 for the construction of a reservoir.

WARRINGTON.—*Bridge.*—The construction of a bridge to replace the existing structure at Poulton is being considered by the Corporation and the Lancs. C.C.

WELLINGBOROUGH.—*Promenade.*—The U.D.C. has applied for sanction to a loan of £3,880 for the construction of a river promenade.

WEST BROMWICH.—*Houses.*—The T.C. has applied for sanction to a loan of £87,000 for the erection of 206 houses.

WIGAN.—*Houses.*—The Corporation proposes to build 100 houses by direct labour.

WIVENHOE.—*Bridge.*—The U.D.C. proposes to erect a bridge across the River Colne.

WOKING.—*Bridge.*—The U.D.C. has approached the C.C. for the provision of a bridge to replace the existing Mayford Bridge.

WOODBRIDGE.—*Road.*—The U.D.C. has agreed with the East Suffolk C.C. to construct a by-pass road at Woodbridge.

WORCESTER.—*Tank.*—The Corporation proposes to erect a tank at the waterworks, estimated to cost £5,200.

WORKSOP.—*Houses.*—The U.D.C. proposes to erect 200 houses.

WORTHING.—*Pier Works.*—The Corporation proposes to spend £4,000 on pier improvements.

YORK.—*Bridge.*—A bridge is to be built across the railway on the Tang Hall Estate.

Tenders Accepted.

ASHFORD.—*Foundations, etc.*—The U.D.C. has accepted the tender of Mr. H. Knock, New Street, Ashford, at £1,779, for the construction of concrete foundations, concrete cooling pond, and concrete road.

BARNSLEY.—*Road Work.*—The T.C. has accepted the tender of Messrs. Hodkin & Jones, at £1,247, for reinforced concrete work at Peel Square.

CARDIFF.—*Concrete Footbridge.*—The T.C. has accepted the tender of Mr. F. F. Thomas, Pearl Street, Cardiff, at £2,187 6s., for the construction of a reinforced concrete footbridge over the River Taff. Other tenders submitted were: J. Sutherland, £2,921 10s.; and A. E. Farr, £2,233 11s.

EDINBURGH.—*Concrete Houses.*—The T.C. has accepted the tender of Messrs. W. Airey & Son for the construction of 500 concrete houses at £375 each.

GLASGOW.—*Concrete Houses.*—The T.C. has recommended for acceptance the tender of the Balshagnay Building Co. for the construction of 250 concrete houses at £478 each.

LENWADE.—*Concrete Bridge.*—The Norfolk C.C. has accepted the tender of Messrs. K. Holst & Co., at £2,900, for the construction of a bridge at Lenwade.

LISKEARD.—*Concrete Culverts.*—The R.D.C. has accepted the tender of Messrs. Christiani & Nielsen, Ltd., at £1,820, for rebuilding in reinforced concrete two culverts and bridges leading to Polperro.

LIVERPOOL —*Concrete Bridge.* — The T.C. has accepted the tender of Messrs. R.&T. Howarth, Rochdale, £5,358 15*s.* 3*d.*, for the construction of a reinforced concrete bridge over Queen's Drive.

NEWPORT, I.O.W.—*Concrete Blocks.*—The T.C. has accepted the tender of Messrs. Ward & Co. for the supply of concrete blocks.

NEWTON ABBOT.—*Concrete Cottages.*—The Council has accepted a tender for the erection of 100 concrete houses.

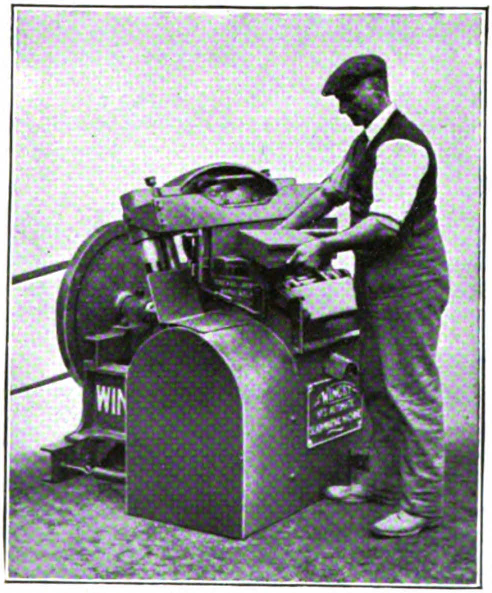
ROCHDALE.—*Concrete Bridge.* — The T.C. has accepted the tender of Mr. J. E. Rangeley, Marigold Street, Rochdale, for the reconstruction of Town Mill Bridge in reinforced concrete.

ROTHERHAM.—*Piling.*—The C.B. has accepted the tender of Messrs. Simplex Piles, Ltd., at £1,021, for reinforced concrete pile foundations.

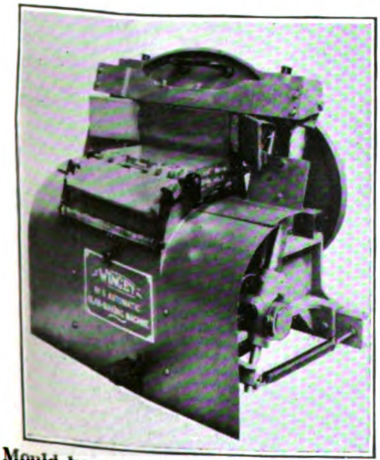
A New Slab-Making Machine.

AN invention which is claimed to create an entirely new labour-cost basis for clinker-concrete slab production has just been placed on the market by Messrs. Winget (1924) Ltd. This is a new automatic slab-making machine, in which improvements have been introduced for the purpose of producing sound slabs in the quickest possible time under a total pressure of 25 tons. With this plant from 165 to 240 slabs can be produced per hour, each 18 in. by 9 in. up to 4½ in. thick on bed with one man operating the machine and another feeding it with mixed concrete.

The machine needs a minimum amount of exertion on the operator's part, and requires only 3 b.h.p. to drive. The mould-box is of the latest Winget design, the two end doors and the front door all opening and shutting together, in each case, with one simple action. When the ram, or head, is pulled over the mould-box this movement at the same time screeds any surplus material from the top of the box. The ram then enters the box, compresses the slab, and returns to its topmost position, where it is automatically held by a Ferodo-lined brake. The ram is then pushed back, while with the other hand the handle is lowered. This automatically opens the box with one movement, and the finished block is ready for lifting away.



Removing the finished Slab.



Mould-box open—ready to receive pallet —with end guard cover removed.

Power is transmitted through a heavy flywheel revolving at 250 r.p.m. through a spring-operated metal-to-metal clutch with Ferodo-lined brake, to a powerful worm-drive fixed on the main crankshaft. The whole machine is well guarded and thoroughly fool-proof.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

			s.	d.
Best Washed Sand	per yard		16	0
Clean Shingle, ¾ in. mesh	„		14	0
„ „ ⅜ in. mesh	„		15	6
Thames ballast	„		10	6
Broken brick (¾ in.)	„		11	6
Best British Portland Cement	per ton	58*s.* to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10*s.* per ton extra			
"Super-Cement"	per ton	88*s.* to	93	0
"Lightning" Brand Aluminous Cement	„	100*s.* to	105	6
Ciment Fondu	works f.o.r.		95	0

Boarding for Shuttering—

		Sawn.		*Wrot.*	
		s.	*d.*	*s.*	*d.*
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £20 „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
9/16 in. to ½ in. Rounds	„	10	9
⅜ in. Rounds	„	11	0
¼ in. Rounds	„	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per yard cube	48	6
Do.	do.	in columns	„ „	53	6
Do.	do.	in beams	„ „	53	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	8
Do.	do.	in floor slabs 6 in. thick	„ „	8	5
Do.	do.	in floor slabs 9 in. thick	„ „	12	3
Do.	do.	in walls 6 in. thick	„ „	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
„ 9/16 in. to ½ in.	„	21	6
„ ⅝ in. to 2⅞ in.	„	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	„ „	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	„ „	1	1½
Do. do. as last, in narrow widths	„ „	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	„ „	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

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Recent Patent Applications.

222,092.—G. J. M. Leicknam: Depositing concrete under pressure.

222,500.—Soc. Lap.: Polished surfaces in cement.

222,501.—Soc. Lap.: Coating metals upon cement surfaces.

225,858.—Soc. Des Ciments Français and Bureau D'Organisation Economique: Manufacture of fused cement.

231,867.—Soc. Lap.: Mixtures of aluminous cements with ordinary cements.

233,351.—B. E. Monteux: Reinforced concrete.

238,635.—A. Brown: Appliance for use in constructing concrete buildings.

238,837.—H. C. Ritchie: Reinforced concrete structures.

238,865.—J. Palanca: Moulds for centrifugal pipes.

238,949.—F. Mulligan: Manufacture of hydraulic cement or plaster from gypsum.

239,092.—D. G. Underdown: Construction of reinforced-concrete slab walls.

239,162.—R. Williams: Centrifugal apparatus for moulding concrete.

239,337.—J. Pickerhill: Concrete kerbstones.

239,375.—J. P. Petty: Production of hollow concrete bodies.

239,435.—R. Preston: Casting concrete buildings *in situ*.

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By W. L. SCOTT, Assoc.M.Inst.C.E.

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MISCELLANEOUS.

PATENTS.

THE owner of British Patent No. 152106 relating to IMPROVEMENTS IN UTILIZATION OF LOW GRADE CARBONIFEROUS MATERIAL IN THE MANUFACTURE OF PORTLAND CEMENT is desirous of entering into negotiations with one or more firms in Great Britain for the purpose of exploiting the above invention, either by sale of the patent rights, or by the grant of a license or licenses to manufacture on royalty. Enquiries to be addressed to MESSRS. ABEL & IMRAY, 30, Southampton Buildings, London, W.C.2.

THE Proprietor of British Patent No. 142121, for improved MANUFACTURE OF CONCRETE or FERRO-CONCRETE PIPES, is prepared to sell the patent or to license British Manufacturers to work thereunder. Address: B. W. & T., 112, Hatton Garden, London, E.C.1.

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239,443.—H. Burger and F. Harbeck: Shuttering clamps.

239,576.—H. Pearce: Manufacture and hardening of concrete products.

240,018.—G. W. Stokes: Reinforcements.

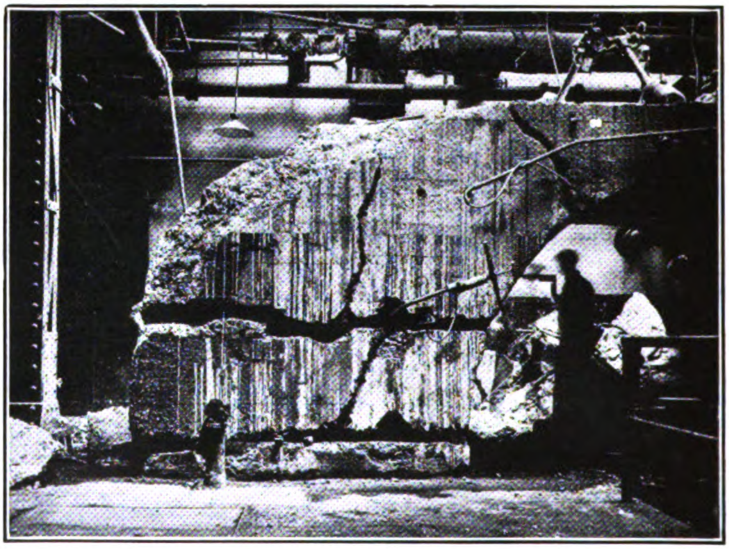
240,041.—S. T. Nielsen.—Process for making mortar and concrete frost-proof.

240,295.—J. P. Petty: Production of hollow bodies of concrete.

240,317.—Moir Buchanan Centrifugal Processes Ltd., and R. A. Whitson: Joint for concrete pipes.

Trade Notices.

Hydraulic Cartridges for Concrete Breaking.—A brochure illustrating the great speed with which concrete may be demolished with the aid of hydraulic cartridges has been issued by the Demolition and Construction Co., Ltd., of 72, Victoria Street, Westminster, S.W.1. With the use of hydraulic cartridges very large masses may be dislodged at one thrust, and in positions where large pieces can be removed without further breaking a considerable economy in time and labour is naturally effected. Under confined indoor conditions as much as 100 tons of concrete has been demolished and removed in one week. A hole of 4-in. diameter is drilled to the desired depth and the cartridge inserted. The operations of boring to a depth of 3 ft. to the completion of the fracture occupy about fifteen minutes. With this method of demolition there is practically no vibration, and consequently no interference with machinery running on an adjoining foundation. We illustrate the effect of the hydraulic cartridge on a mass of concrete at the Lots Road power station of the Underground Railway Company, showing the disruptive effect of one hydraulic thrust.



Super-Cement.—A paper read by Mr. J. F. Goddard before the Institute of Builders at Liverpool has been reprinted by Messrs. Super Cement, Ltd., of 10, Upper Woburn Place, W.C.1, who will send copies to those interested on receipt of their professional or trade card. The paper is entitled "On Certain Cements and Their Properties," and fully covers the ground indicated.

Concrete Roads.—"Notes on the Use of Reinforced Concrete in Road Work" is the title of a useful pamphlet issued by the B.R.C. Engineering Co., Ltd. It deals with preparation of subsoil, proportioning and mixing of concrete, and the reinforcement of concrete roads.

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

MARCH 1926 **VOL. XXI No. 3**

CONCRETE SERIES No 1

TWENTY-FIRST YEAR OF PUBLICATION

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XXI. No. 3. LONDON, MARCH, 1926.

EDITORIAL NOTES.

Concrete in Architecture.

DISCUSSIONS on the architectural future of concrete are always of interest, and the views expressed last month were no exception. We hear, however, little that is new on the subject ; the stock phrases of the architectural critics are so often repeated that we are in danger of thinking there is nothing more to be said on the question—concrete, we are told, must have a style of its own which will be expressive of the material, although what that style should be nothing but the future will tell. A correspondent, getting away from this generally-accepted view, asks some pertinent questions in a letter given in part below. " Why," he asks, " should we be eternally asked to grope for a particular style for concrete ? For what are we seeking ? Is our object to search for a style which the critics will tell us is ' a truthful expression of the material,' and then use concrete in that style and no other ? And if so, is this object a desirable one ? Far better, in my opinion, to follow the precedent set by other building materials, and arrange the parts of the building so that they shall be pleasing to the eye while at the same time the structure fulfils the purpose for which it was erected. ' Design in beauty, build in truth,' was the motto which inspired the old builders who first attempted to combine beauty with utility in whatever material they were using. They did not set out to arrive at a ' style,' and the result was not one style but many. We do not say that stone must have one style of its own, and one only. We can see that it may be as applicable to such totally different styles as Gothic and Renaissance, and the results as structurally sound and artistically good in either case. Stone is recognized as a building material of general utility, which may be used in any one of half-a-dozen styles without adverse comment. This being so, why should we look for a style for concrete as a thing apart ? We are told that concrete must express strength and durability. Most of us know structures built in stone that express these attributes in their highest form : but because they are based on a stone style must we infer that a structure built in concrete to exactly the same design would not meet with the approval of those architects who are seeking an entirely new style for this material ? We know the essential properties of concrete are strength and durability ; but so are these the attributes of granite, and it is difficult to see how the same qualities are to be expressed in different ways in different materials. Of course, enormous cantilevers are possible in reinforced concrete, but except for grandstands and such-like structures they are not required in modern buildings, and so do not affect the issue. Concrete and reinforced concrete may be used for the most massive or the most slender types of construction. Concrete may be moulded to the most minute detail of ornamentation. It seems to me that this striving after something entirely new is wasted effort, and that we shall get the best results in concrete, as with stone, by building in the style most suitable to the occasion. If we 'design in beauty and build in truth' we shall get a building which is good to look upon and suitable for its purpose without the need for seeking a new style. It would be interesting to have the views of your readers on this subject, especially if they would forget the platitudes we have heard so often and think along the lines of the above somewhat rambling notes."

While we do not necessarily agree with all our correspondent says, we would welcome a discussion on the subject. Certainly there are many points made in the course of discussion which need a clearer definition. Why, for instance, should it be an axiom of the critics that the members of a reinforced concrete building should be exposed in the cause of "truth" in construction? We have never yet heard it suggested that a steel frame should be exposed on the surface of a building, yet the cases are exactly the same.

Concrete Scholarships.

WHEN, in our January issue, we announced that the proprietors of this journal had given an annual prize for reinforced concrete design for competition among the students at London University School of Architecture, and expressed the hope that others with the cause of education in concrete at heart would offer prizes for the same purpose, we must admit we did not think our lead would be so quickly and handsomely followed. The first result was the offer of a scholarship value £300 by the British Portland Cement Association, and we are now able to announce that a firm of reinforced concrete engineers has offered a further scholarship of the same amount to be awarded every third year in a competition to be set by the Institution of Structural Engineers.

The conditions of the prize offered by the British Portland Cement Association provide that the winner is to travel for fourteen days on the Continent and in the United States for twenty-eight days, short enough periods for a thorough study of such a subject as reinforced concrete, but which should enable the winner to obtain some idea of the development and latest methods in use in the countries visited. The observations made on the tour are to be put in writing, and will, we hope, be made public. The conditions of the second scholarship have not yet been announced.

These prize funds should be of very great value to the industry, not only in providing the means for the winners to travel abroad, but in stimulating a close study of the subject amongst the large numbers whom we hope will enter the competitions.

Engineering Failures.

By EWART S. ANDREWS, B.Sc., A.M.Inst.C.E., M.I.Struct.E.

THOSE who have studied American technical literature for the past twenty years will be familiar with Mr. Godfrey's frequent contributions to those discussions and controversies which take so much more violent form in that country than we are accustomed to here. Mr. Godfrey is full of pep and energy, and with increasing hurricane force as the years have progressed he has carried on a holy war attacking what he believes to be heresy in design—heresy based upon a bolstering up of false theory and a neglect of "horse sense." He has now issued in book form * a collection of his writings with the hope that the errors to which he attributes many failures and much loss of life may not be repeated in future by designers who follow what he feels to be the blind lead of the professors. Most men who feel impelled to reform the world in their youth sober down as their age and experience grow, but Mr. Godfrey is surely the Peter Pan of the structural iconoclasts—he is just as aggressive and just as impatient of error as he ever was.

The book before us is stimulating, interesting, forceful and valuable, and although the author expresses great contempt for mathematics, we feel that his attitude arises not so much from lack of mathematical knowledge as from the way in which some mathematicians neglect the facts of engineering life in their desire to maintain their formulæ. We understand that Mr. Godfrey has held for many years a responsible post as engineer to a very important firm of American engineers, and his views are based largely upon first-hand knowledge of the designs which he condemns and the failures which he describes.

There are three principal targets against which the high-explosive ammunitions of the Godfrey gun are aimed—they are "Under-pressure in Dams," "Shear in Reinforced Concrete Beams," and "Rodded Columns in Reinforced Concrete."

The first of these deals with the contention that the underside of a dam in almost every practical case can be subjected to an upward pressure corresponding to the head of water retained by the dam. In most designs of dams this under pressure is neglected, and Mr. Godfrey maintains—and gives several examples of failures in support of his arguments—that many failures can be explained only on the assumption that this under-pressure occurs.

The second subject is one on which Mr. Godfrey has already read a paper before the Institution of Structural Engineers. Most engineers in this country who have given much attention to the important subject of shear reinforcement agree in the main with Mr. Godfrey's contention, and it is interesting to note that most of the designs which he condemns would not be permitted under the London Regulations.

Mr. Godfrey has also read a paper before the same Institution on the question of reinforced concrete columns. By a "rodded column" he means a square column with a small rod at each corner, light transverse bracing being provided at comparatively long distances apart; he quotes a large number of failures—with references to technical journals which can be verified—in which there has been severe loss of life, and he maintains that the use of rodded columns accounted for the failures. He contends also that there is no failure on record of a reinforced concrete building employing octagonal or round columns with spiral reinforcement; he maintains that a column must possess "toughness" which enables it to resist bending, and states that there is no case on record of a wreck of a steel-frame building employing continuous columns. We believe that many of the wrecks to which he refers can be attributed to the failure to provide for the bending moments in columns—a point to which Dr. Faber and other British engineers have often called attention—but the evidence that he provides is clearly sufficient to show that great care is necessary in the provision and anchorage of the lateral reinforcement for columns.

Many of the failures described in the book are attributed to neglect of ordinary rules of construction rather than omission to make the calculations according to orthodox theory; the failure of the roof of the Knickerbocker Theatre in January, 1922, is an interesting example of this, and the following particulars are quoted from the book.

---

* "Engineering Failures." By Edward Godfrey. (Published by the author at Monongahela Bank Building, Pittsburgh, Pa., U.S.A. Price 3 dollars.)

" The walls were a combination of tile placed with the cells vertical and a facing of brick.

" A tile wall cannot be commercially built strong when the cells are placed vertical. The reason is that there is no surface to receive the mortar for a horizontal joint. No tile-layer is going to potter around laying mortar on the thin ribs of a tile. In any event these ribs may not ' register ' in two tiles one above the other. The workman will put on just enough mortar to steady the tile and furnish a joint on the face of the wall. If a close steel mesh were laid in each horizontal joint, a good joint could be effected, but this is only practicable in a laboratory. Single tiles are stronger when tested in a laboratory with the cells vertical than with the cells horizontal, but this fact has an academic interest only when walls cannot be built with good joints with the cells of the tiles vertical.

" There were other faults in the design and construction of the Knickerbocker Theatre. In fact every part of the construction was weak, including the roof slabs, the roof beams, the roof trusses, the columns and the walls. But it was not general weakness that caused the failure. As is generally the case, a fundamental principle of stability or equilibrium was violated. At least two principles of stability were violated, and the probabilities are that these contributed jointly to the failure. Little emphasis has been placed on these two points of weakness, but much emphasis has been placed on the general weakness, of the structure. No lesson of value is to be learned by emphasising the folly of general weakness in a design, if that emphasis obscures some subtle fault. Every conscientious engineer avoids such things; a wreck is not needed to point the lesson. But there are certain principles of stability which are partially or totally obscured in works in engineering, so the poor designer, who may not have dug out these principles for himself, is not aware of the unstable equilibrium of his structure. It is these principles that ought to be blazoned on the housetops whenever a wreck demonstrates their importance.

" The other great weakness of the

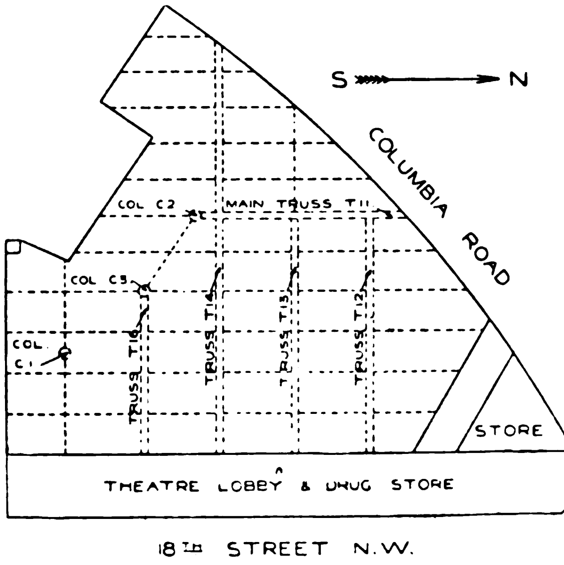


FIG. 1.

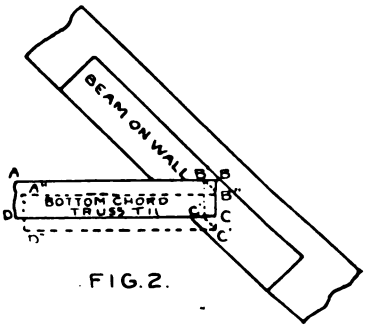


FIG. 2.

Failure of Roof of Knickerbocker Theatre.

design (in addition to the combination walls) is the support of main roof truss T 11. *Fig.* 1 illustrates the roof plan of this building. Truss T 11, on which the great part of the roof was supported, rested on a combination wall at an angle of nearly 45 degrees. It was not anchored to the wall, and by the process of expansion and contraction it gradually worked off the wall. The seat in the wall was a steel beam. Probably this beam was low on the inner edge of the wall, due to the yielding of the tile shell of the wall, and this slope aided the truss in sliding off the support as it did. In any event the failure can be explained in this way, and this explanation fits every feature of the wreck. In *Fig.* 2, suppose ABCD is the original position of the truss on the wall. After the first contraction points B and C move to B′ and C′ respectively. In expanding, instead of forcing these points back to B and C, the truss chord will slide along the edge of the I-beam, and B and C will be in the positions B″ and C″. The perpendicularity of the truss is thus destroyed, and also the wall is impaired by the force pushing it outward. The wall was actually pushed out about 5 in. at the top, when the truss gave its final kick and slid off the wall.

"The progressive failure of this roof-truss by gradually slipping off the wall would not show up in the ceiling, as one engineer claims, because of the fact that the end panel of the truss was free, the ceiling beams being supported a panel length away from the end of the truss."

Readers are strongly advised to study this book; it has evidence of the weakness possessed by Mr. Dick who could not keep King Charles' head out of his Memorial, but it contains much wisdom; those who read the book will, no doubt, come to the reassuring conclusion that the writer has reached, viz. that the average standards of design and construction in this country are superior to those obtaining in the United States.

Combined Bending and Direct Force.

MR. CHARLES E. REYNOLDS, B.Sc., has sent the following reply to Dr. Nicholas Kamm's criticism of his article on "Combined Bending and Direct Force." Mr. Reynolds' article was given in our issue for December, 1925, and Dr. Kamm's criticism in our February issue:

I read with interest Dr. Kamm's critical appreciation of my article on "Combined Bending and Direct Force."

It appears that Dr. Kamm does not question the accuracy or propriety of the method I proposed, much of his criticism being merely on preference of methods of calculations, for which he claims equal simplicity. I venture to suggest that relative simplicity is a matter of personal experience and opinion. For this reason, therefore, I would not contemplate a detailed reply, were it not that there are certain misstatements in the mathematical expressions given by Dr. Kamm which tend to make them misleading.

The formulæ referred to are those in Case 3. Using the symbols adopted by Dr. Kamm, his equations, I suggest, should read thus:

$$M_t = A_c v[d - f] + \frac{cbn}{2}\left[d - \frac{n}{3}\right]$$

giving $$A_c = \frac{M_t - C_c a_c}{v[d - f]}$$

and $$M_c = A_t \cdot t[d - f] - \frac{cbn}{2}\left[\frac{n}{3} - f\right]$$

giving $$A_t = \frac{M_c + C_c\left[\frac{n}{3} - f\right]}{t[d - f]}$$

With these corrections I am inclined to agree with Dr. Kamm that for the particular case in question his method is perhaps clearer, although the number of intermediate mathematical steps is about the same as in my method. I do not think, however, that the method Dr. Kamm gives for the solution of Case 4, when compared with the corresponding case in my article, has the advantage of greater simplicity, which the author evidently claims for it.

Dr. Kamm's chief objection seems to be the proposed method of determining the position of the neutral axis, which he suggests should be evolved from the fundamental cubic equation, or from curves giving the values of "*n*," such as are given, for example, by Mörsch. The most comprehensive and elaborate curves for this purpose are probably those given in Hool and Johnson's "Concrete Engineer's Handbook," p. 394 *et seq.*, but even these have only a limited scope, being dependent on a definite ratio (*e.g.* unity) of tensile to compressive reinforcement, on definite ratios of "cover" to effective depth, and on a specified modular ratio. The idea of assuming a value of "*n*" is one that is commonly used, and is adopted, for example, by Dr. Oscar Faber in his treatment of the subject of combined stress as given in *The Builder*, January 5, 1923. It is a method that gives that arithmetical simplicity which is aimed at, and with but little practice the closeness with which a satisfactory value of "*n*" can be estimated renders it usually unnecessary to make the double calculation.

In practice, the method that commends itself to the busy designer is one that with reasonable accuracy is applicable to all similar problems; that is not arithmetically complex, but attains the result by easy stages, thereby eliminating the probability of numerical errors; that is preferably not entirely dependent on any one definite source of data; and that is readily memorised. I submit, therefore, that such a method as I suggest, in which a reasonable reference axis is so chosen as will facilitate computations, fulfils the above conditions for all cases where the eccentricity of the direct force is larger than about one-and-a-half times the effective depth of the section considered.

One concurs with Dr. Kamm in his statement of the importance of this subject of combined stresses, and the interest which is displayed is evidenced by correspondence received and by the appearance of Dr. Kamm's notes, which make adequate contributions to the treatment of this practical problem.

Note.—In dealing with Case 4 in the original article, the statement that "the limit of economical design" is reached when the areas of compression steel and tension steel are equal, was a clerical error, and is misleading. This should have read "the limit of rational design, etc."

Books Received.

"Comparative Tests of Button Head and Countersunk Riveted Joints." By J. B. Kommers. (The University of Wisconsin, U.S.A. 59 pp. Price 15 cents.)

"Experimental Works in Reinforced Concrete." By M. K. Duraiswami Ayyar. (This is a paper, extending to 72 pp., read by the author before the Madras Local and Municipal Engineers' Association, and deals largely with reinforced concrete work in Sivaganga State. The report contains a large number of plates giving details of various types of structures, and many photographs, and should do much to popularise this form of construction in a country where at present it is not used on an extensive scale.)

"La Construction Économique." By M. Vugnon. (Paris: "Revue des Matériaux de Construction." 148 pp.; 56 illus.)

"Einflüsse auf Beton." By F. Hundeshagen, Otto Graf, and A. Kleinlogel. 450 pp.; 150 illus. (Berlin: Wilhelm Ernst & Sohn. Price M. 21.60.)

"Laboratoriumsbuch für die Portlandzementfabrik." By Dr. Franz Killig. 142 pp.; illus. (Charlottenburg: Zementverlag G.m.b.h.)

New German Regulations for Reinforced Concrete.

A REPORT on the principal alterations in the new German Regulations for Reinforced Concrete, based on Professor Löser's review, appeared in a recent issue of *Zement*, from which the following abstract is taken :

For the first time high-strength cements are recognised officially and the compressive strengths to be reached at different ages are specified as :

3 days old, 3,550 lbs. per sq. in.
28 days old, 7,100 lbs. per sq. in.

In future 1 cubic yard of concrete in place must contain 508 lbs. of cement, and the compressive strength of concrete 28 days old, measured on 8-in. cubes, must reach 2,840 lbs. per sq. in., and 3,900 lbs. per sq. in. when rapid-hardening cement is used. With the latter cement the recognised times for removing shuttering shall be

2 days for beam and column sides,
3 days for slabs, and 8 days for beams.

Steel must show at least 18 per cent. elongation and an ultimate strength of 68,000 to 82,000 lbs. per sq. in. At least 0·5 per cent. reinforcement shall be used in columns in which $\frac{l}{d}$ is equal to 5. If $\frac{l}{d} = 10$, then, 0·8 per cent. of steel is required.

The Euler formula for buckling of columns has been abandoned, and the simpler relation

$$\omega \times P = f_c \times A_c$$

incorporated in the regulations. Here w is greater than 1 and its value can be interpolated from the table below :

Columns without Spirals.		Spirallcd columns.	
$\frac{l}{d}$	ω	$\frac{l}{d}$	ω
15	1·00	13	1·00
20	1·25	20	1·70
25	1·75	25	2·70

Moments in Slab Continuous Over Supports.

With uniform loading and approximately equal spans, the moments shall be :

End span.	Interior spans.	Ends of slab.
$\frac{wl^2}{12}$	$\frac{wl^2}{18}$	Haunched
$\frac{wl^2}{11}$	$\frac{wl^2}{15}$	Not haunched

Whether a haunch occurs at each end of a span or not the moments at the supports shall be reckoned as $-\frac{wl^2}{10}$ at an interior support and as $-\frac{wl^2}{9}$ at the end support but one.

In each span provision shall be made for a negative moment at its centre based on the relation

$$M = \frac{1}{24} l^2 (g - \tfrac{1}{2}p),$$

where g = dead uniform load per unit length,
p = live uniform load per unit length,
and $(g + p) = w$.

Flat Slabs.

If l_x and l_y denote the lengths of the sides of a panel, then the minimum column side

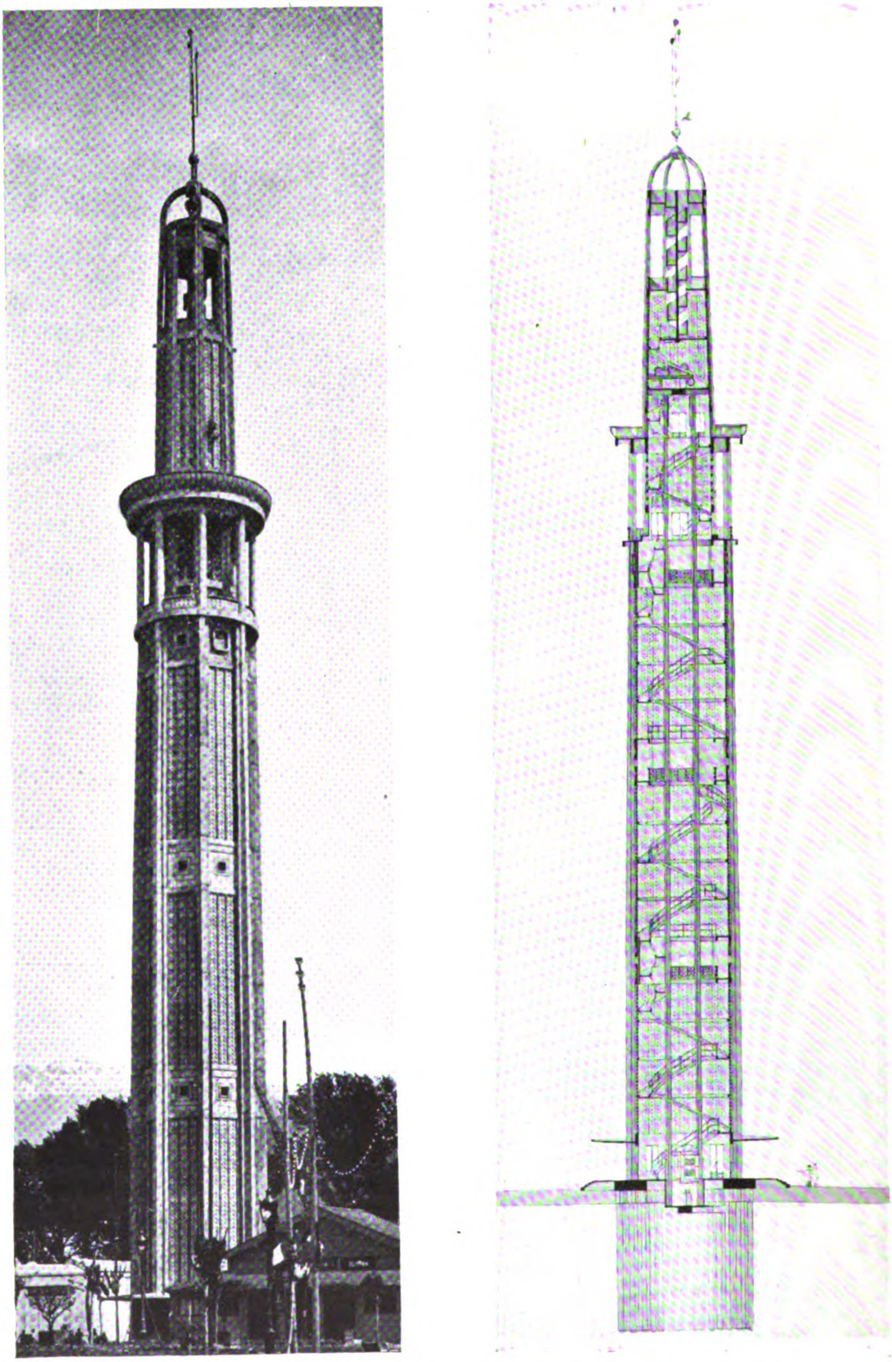
$$= \frac{1}{20} \times \frac{l_x + l_y}{2}$$

and in no case shall it be less than 12 inches or $\frac{1}{15}$ × distance between the floors of the building.

Minimum thickness of slab

$$= \frac{1}{32} \times \frac{l_x + l_y}{2}, \quad \text{or}$$

6 inches for floors, and $\frac{1}{40} \times \frac{l_x + l_y}{2}$, or 6 inches for roofs.



Reinforced Concrete Tower at Grenoble. (*See p.* 233.)

Bending Moments in Columns.

(1) At foot of upper column

$$M = \frac{l_x{}^2 l_y}{12} p \times \frac{C_0}{C_0 + 1 + C_u}$$

(2) At top of lower column,

$$M = -\frac{l_x{}^2 l_y}{12} p \times \frac{C_u}{C_0 + 1 + C_u}$$

where $C_0 = \frac{lJ_0}{h_0 J_d}$ and $C_u = \frac{lJ_u}{h_u J_d}$, in which

h = height of column, p = uniform live load,

l = span of beam,

J = moment of inertia (J_0 for upper and J_u for lower column).

For calculation of the bending moments in exterior columns the same formulæ are to be used with the exception that p will be replaced by w, the total uniform loading rate.—W. S. G.

Reinforced Concrete Tower at Grenoble.

By P. Calfas, Paris.

The Water Power Exhibition, which has been held at Grenoble, included several interesting reinforced concrete buildings, the most conspicuous of which was the "Orientation Tower," a permanent structure which has become a great attraction to sightseers.

The tower, 263 ft. high, is octagonal in section and supports at the height of 197 ft. a circular gallery provided with a large orientation table. From this terrace one obtains a remarkable view over the surrounding Alpine ranges. Above the terrace the tower becomes a campanile 66 ft. high, at the top of which electric projectors have been installed.

The tower was designed by MM. Perret, architects, and M. Gellusseau, engineer. It consists chiefly of eight pillars forming the octagonal section, and these are linked by thin walls provided with openings for the admission of light to the interior.

The structure is on a very bad soil which, to the depth of 36 ft., consists of soft clay nearly always impregnated with water. Consequently it is founded on 72 concrete piles, built according to the "Simplex-Soly" system (i.e. the concrete being poured *in situ*) and reinforced in their upper part over a length of 16 ft. The heads of the columns are coupled together by a crown of 37½ ft. external diameter and having a cross-section 8 ft. 6 in. wide by 2 ft. 8 in. thick, in which the eight columns are embedded and are linked together at a height of 197 ft. by three bands. From the top of the third band starts the spire of the tower, which rises to a height of 275 ft. 7 in.

The filling between the pillars consists of panels 2 ft. by 2 ft. 8 ins. by 4¾ ins. thick, provided with openings to admit light to the interior. The external facing has the appearance of tiles, thus allowing for the dripping down of rain water.

Access to the interior of the tower is by a double staircase, which reaches the level of the platform.

Two electric lifts run up to the level of the terrace.

The total height of the structure to the top of the spire is 312 ft., and 915 cubic yards of concrete were used in its construction.

Concrete Foundations for Wooden Posts.

A method of prolonging the life of wooden transmission-line posts which have decayed at or below ground level is being adopted by the Toronto Hydro-Electric Power Commission. The poles thus decayed are cut through a few inches above ground-level and moved while the decayed stump is removed. Into the hole from which the stump has been removed is placed a pre-cast concrete slab with a cavity through the middle into which the pole is placed and fixed. It is claimed that this method of making use of that part of the pole above ground-level costs less than 50 per cent. of the cost of a complete new pole.

Reinforced Concrete in Relation to Present-day Design.

MR. OVE ARUP writes: It is with much interest that I have read the article by Professor A. E. Richardson in the January issue of *Concrete and Constructional Engineering*, concerning reinforced concrete in relation to present-day design, and while I fully agree with most of his remarks, it occurs to me that the part played by the engineer in the development of the artistic design of reinforced concrete structures has been slightly under-estimated in this article.

Professor Richardson describes the architect as the deviser or planner of structures, while the engineer acts more in the capacity of his technical adviser. This no doubt applies in the case of all ordinary buildings made up of columns, beams, walls, and slabs, where the arrangement of the rooms to suit the different purposes of the building is the governing factor in the planning, but in the case of actual engineering works, such as arch bridges with big spans, silos, hydraulic structures, etc., the position is somewhat reversed. Here it is the engineer who of necessity is the planner of the structure and decides upon its main proportions, whereas the architect acts as adviser in matters of detail, such as the arrangement of railings, copings, etc.

Now I venture to suggest that the best architecture in reinforced concrete is generally to be found among those big engineering structures of to-day rather than in ordinary building planned by architects. And the explanation of this appears to be quite simple. First, a well-designed engineering structure generally possesses a quality which is more and more accepted as an essential feature of good architecture, namely "truth," whereby it is implied that the purpose of the building or structure is met in a simple, logical, and economical way, and that this purpose is openly and frankly expressed in the building, without disguise of any kind, but with respect for, and knowledge of, the material employed.

As regards knowledge of the material, this belongs to the sphere of the engineer, and is naturally most advanced amongst engineers. But, furthermore, in the case of a utility building or engineering structure the purpose itself is simple and clearly stated, and naturally imposes itself as the main consideration—a bridge is to carry a certain traffic over a certain distance; a silo must contain a certain amount of material and deliver it at certain points. From an architectural point of view the proposition is a simple one—what is required is straightforward efficiency.

If, therefore, an engineer with a thorough knowledge of the material succeeds in creating a structure which combines a high degree of efficiency with economy in design, this structure automatically satisfies one of the first claims in architecture.

In ordinary building (as, for instance, a school, a town-hall, a dwelling-house) the architectural problem is much more complicated. There are a hundred different considerations to conciliate. The possible solutions are much more numerous even if truth and simplicity are aimed at, because even small alterations in the proportion and number of windows, in

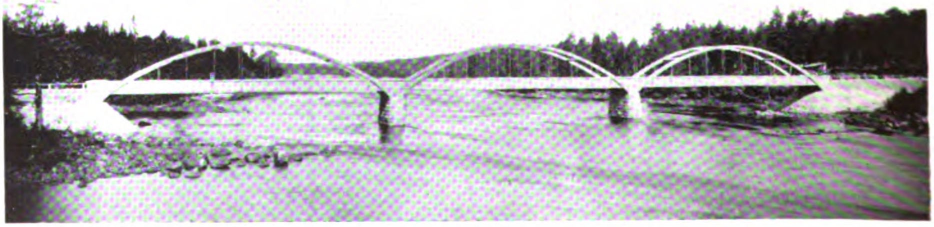


Fig. 3.—Reinforced Concrete Bridge at Ljusne Elv, Sweden.

the sloping of the roof, in the arranging of panels, in the surface treatment, etc., may be of great consequence, and may completely alter the style of the building. A thorough knowledge of the material is, therefore, not sufficient in this instance.

Faced with these problems, the architect is naturally inclined to apply traditional forms and proportions, which were natural for brick and stone, but which do not fully utilise the extended possibilities of the new material. It must be the aim of architects to develop a new form of architectural beauty which does justice to the material without taking refuge in disguise. In many modern reinforced concrete buildings as, for instance, some American and Continental stores, this is also more and more acknowledged.

Another difficulty which has hampered the development of a reinforced concrete architecture is that although reinforced concrete is an excellent material where strength and durability are required, and therefore specially suitable for engineering structures, it does not excel in, for instance, low thermal conductivity, lightness and sound-proofness. It has therefore been usual to combine it with other materials, and the character of the building as a reinforced concrete construction is thereby to some extent lost, and is often deliberately hidden. The introduction of light and insulating cellular concretes, which do away with these disadvantages of ordinary concrete for building, indicates a way out of these difficulties. But these materials are of such recent introduction that they have not yet affected the architecture of concrete buildings.

It is only natural that the best treatment of reinforced concrete at this stage is to be seen in the domain where the knowledge of reinforced concrete is most advanced, where the properties of reinforced concrete are of most value, and where the architectural proposition is the simplest possible. This, however, does not imply that a collaboration between architects and engineers is not highly desirable in the case of engineering structures. Most structures would profit immensely by such a collaboration, provided of course that the architect treats the reinforced concrete structure as such and does not try to apply ornaments and decorations taken from quite different domains; and it is to be hoped that the clients will more and more realise that it is worth paying the price for this collaboration.

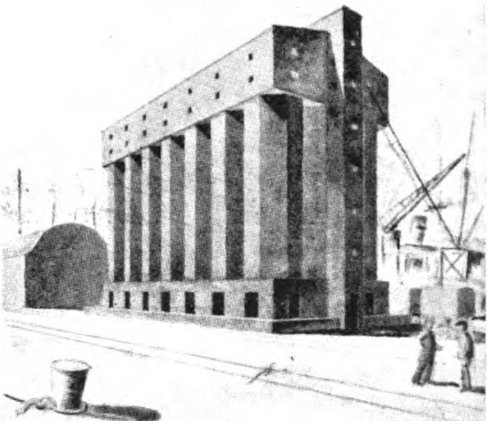


Fig. 6.—Grain Silo in Denmark.

The development of a reinforced concrete architecture which is able to compete in harmony and expression with the stone and brick buildings of former times is finally in the hands of the architects, but perhaps at this stage they might learn something of the treatment of the material by studying the simplicity and efficiency of some of the modern utility structures.

Some illustrations of reinforced concrete arch bridges are given, for the loan of which I am indebted to Messrs. Christiani & Nielsen. *Figs.* 1 and 2 show two different projects for a combined railway and highway bridge over the Little Belt, Denmark. The bridge was intended to supersede the existing ferry service between Jutland and the island Fyen. In one case the carriage-way is arranged above the railway, in order to save width, in the other case the carriage-way is level with and situated between the two railway tracks.

Fig. 3 shows a reinforced concrete arch bridge over Ljusne Elv, Sweden. The exceptional slenderness of the arches is due to the fact that they were designed to take compression only, all moments from the live load being taken up in the parapet beams.

The bridge over the river Fnjoska, in Iceland, was built as early as 1908. In your January issue this bridge was

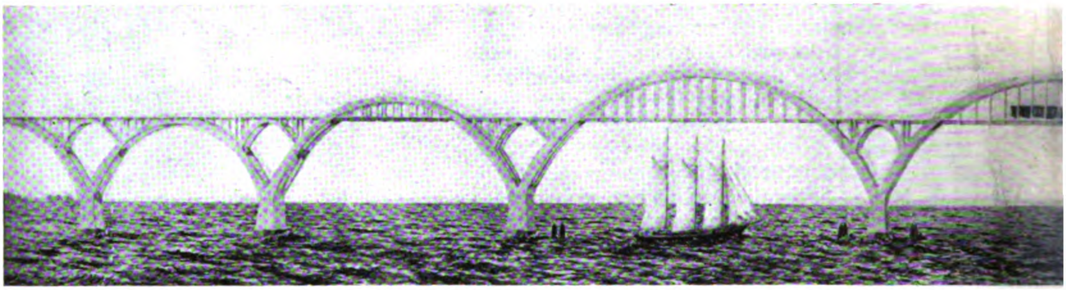


Fig. 4.—Design for a Railway Bridge bet

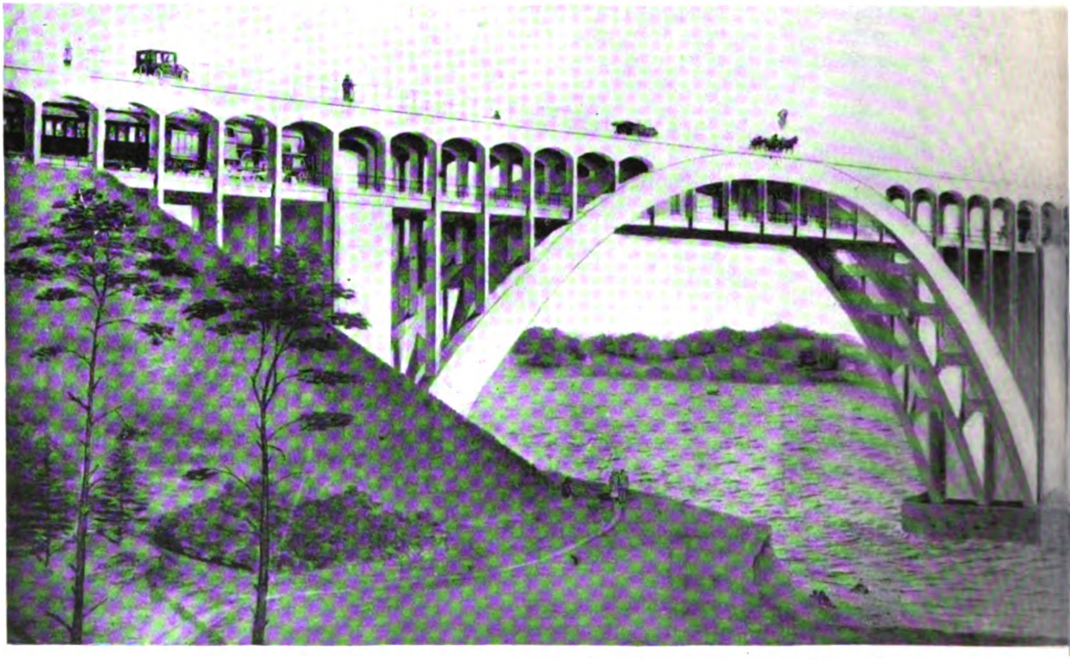


Fig. 1.—Design for Combined Railway and Hig

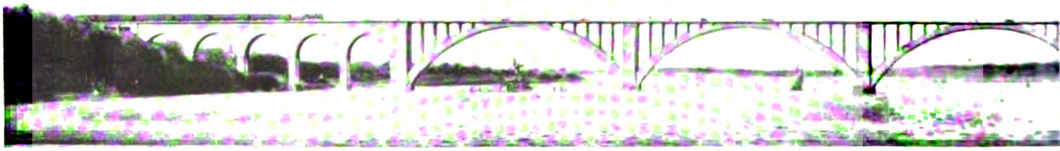
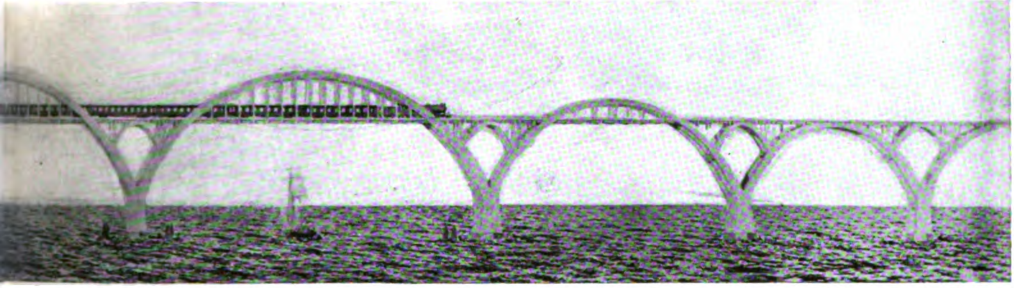


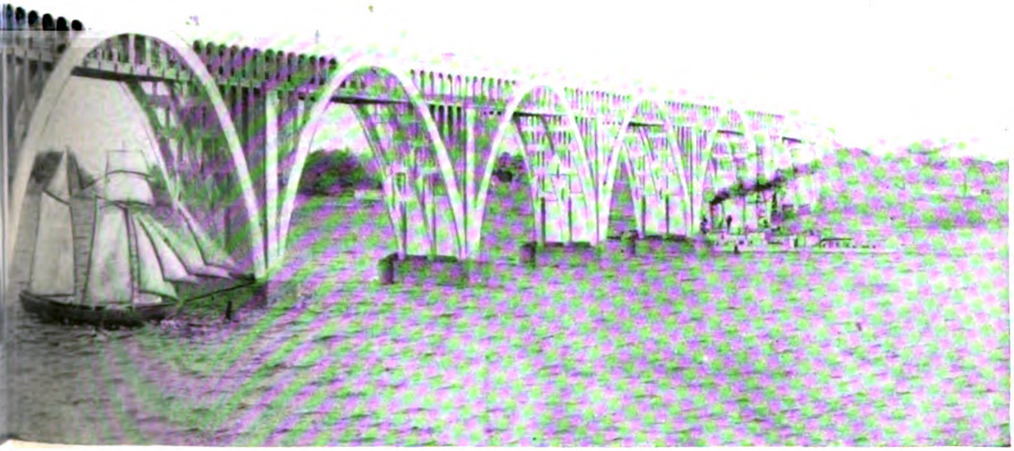
Fig. 2.—Alternative Design for Combined Railway

DESIGNS FOR REINFORC

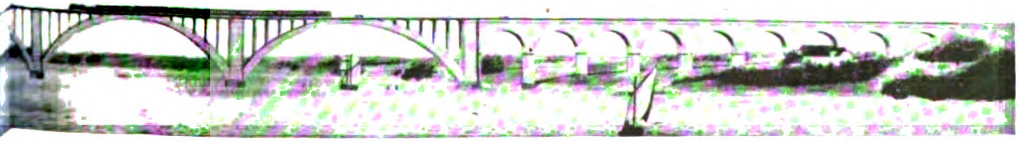
(By Messrs. Chri



ween Masuedoe and Falster, Denmark.



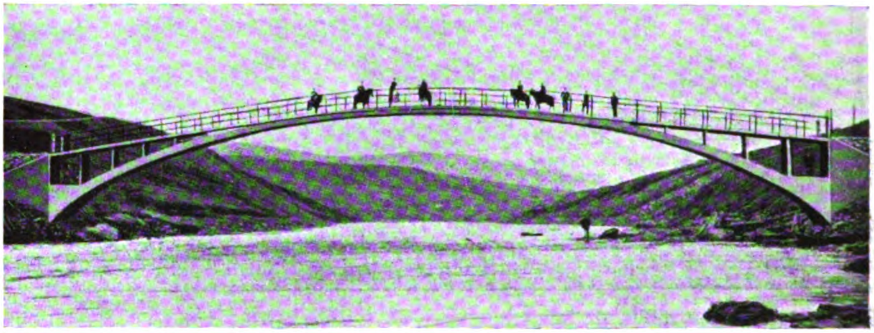
hway Bridge over the Little Belt, Denmark.



and Highway Bridge over the Little Belt, Denmark.

ED CONCRETE BRIDGES.

hani & Nielsen.)



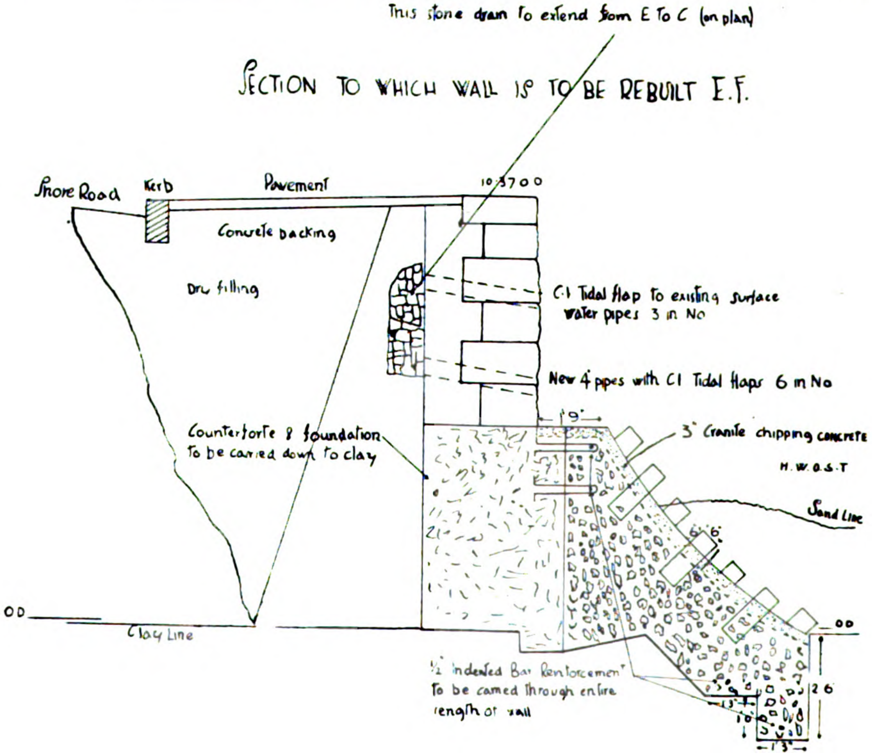
Reinforced Concrete Bridge over the River Fnjoska, Iceland.

wrongly referred to as a bridge in Switzerland.

Fig. 4 shows part of a project for a high railway bridge between Masuedoe and Falster, Denmark. The bridge was to be in 144 spans of a total length of 22,000 ft.; maximum span, 328 ft.; highest level of rail, 111 ft. above surface of water; width, 33 to 40 ft.; foundation on pillars in a depth up to 75 ft. below water-level.

Fig. 6 shows the result of collaboration between architect and engineer. This is a project for a grain silo, of about 7,000 tons capacity, designed by C. F. Möller and John Thorson, architects, and H. M. L. Lauesen, engineer, of Copenhagen.

The bridges illustrated were designed by Messrs. Christiani & Nielsen.


This stone drain to extend from E To C (on plan)
SECTION TO WHICH WALL IS TO BE REBUILT E.F.
Shore Road
Kerb
Pavement
10.3700
Concrete backing
Dry filling
C.I Tidal flap to existing surface water pipes 3 in No
New 4" pipes with C I Tidal flaps 6 in No
Counterforte & foundation to be carried down to clay
1'9"
3" Granite chipping concrete
H.W.O.S.T
Sand Line
6" 6"
2'1"
OD
Clay Line
OD
½" Indented Bar Reinforcement To be carried through entire length of wall
1'3"
1'0"
2'6"
1'3"

New Sea-Wall at Swanage. *(See p. 239.)*

Sea Defences at Swanage.

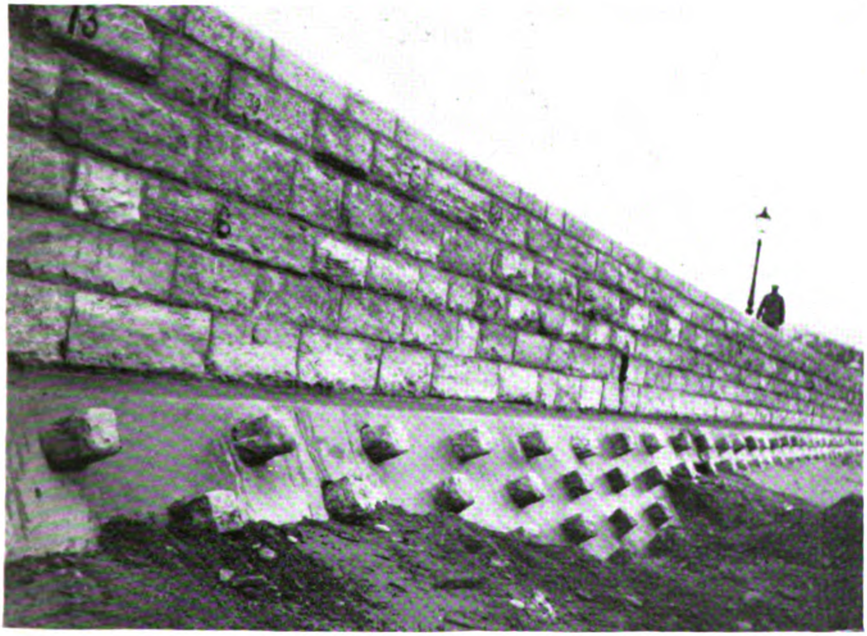
In our issue for July, 1925, we described a section of the sea wall at Swanage that had been reconstructed. A further section of this wall, 294 ft. long, was damaged in December, 1924, and this has also now been reconstructed.

This section collapsed through the heavy seas sucking out the shingle from beneath the foundations and leaving them unsupported over long lengths so that they cracked, subsided and finally toppled over into the sea.

The new foundations are composed of mass concrete, attached to which is a curved apron with a toe-piece projecting into the clay about 2 ft. 6 in. The concrete was composed of 1½ in. graded stone with sufficient sand to fill the interstices in the proportion of 1 part rapid-hardening Portland cement to 7 aggregate. The foundation was cast continuously and at the finish of each day's work ½ in. reinforcing bars were introduced for connecting the next day's work.

The curved apron was cast on to the concrete foundation, from which ½ in. mild steel loops projected and through which were threaded two ½-in. mild steel rods. The apron was cast in 9 ft. alternate bays, and faced with 3 in. granite concrete in the proportion of 1 part rapid-hardening Portland cement to 2½ parts granite aggregate.

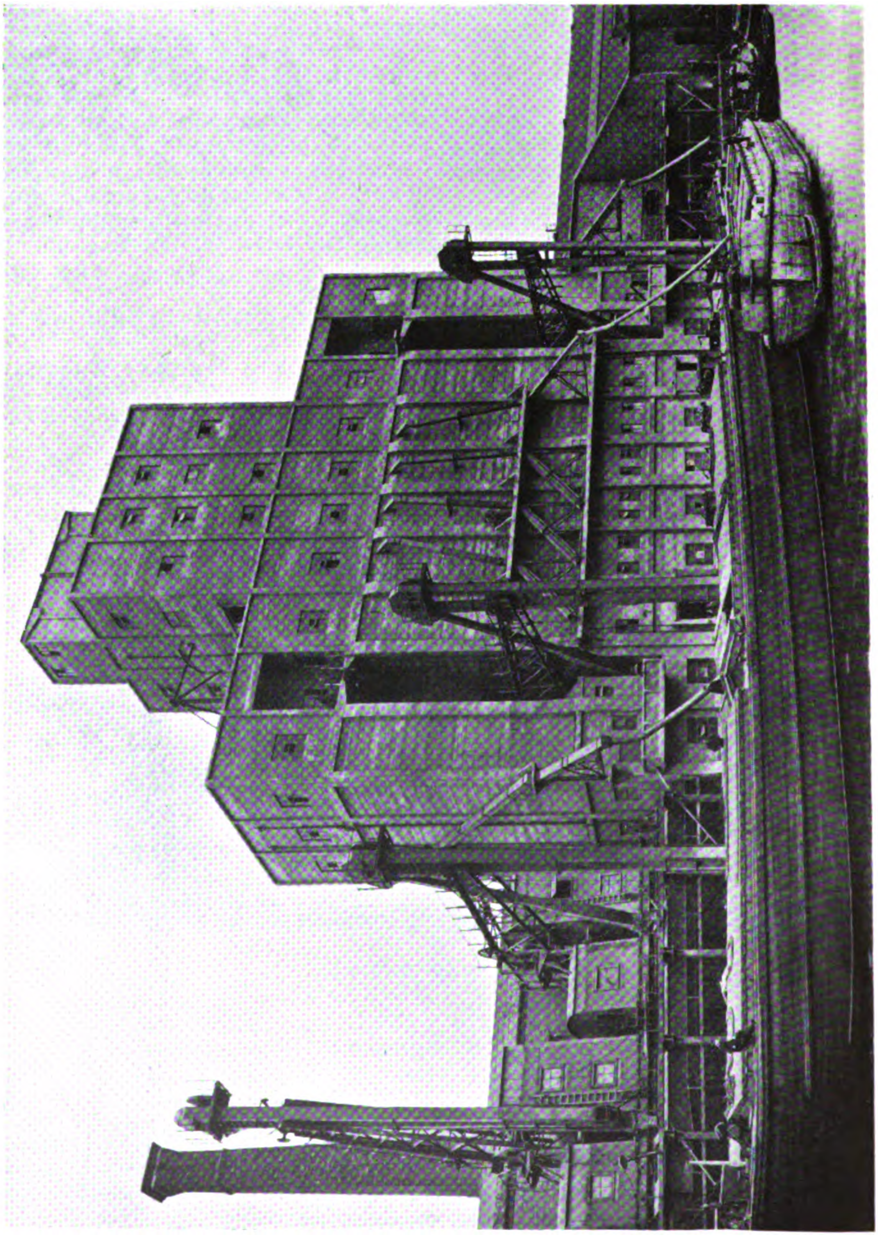
Hard Purbeck stone setts, 6 in. square by 18 in. deep, and projecting 6 in. from the surface, were fixed in the apron at 2-ft. centres to assist in breaking up the waves. The concrete foundations were surmounted by hard Purbeck stone blocks, backed with concrete, the wall being additionally strengthened with concrete counterforts spaced at 22-ft. centres.



New Sea Wall at Swanage.

The wall has been severely tested during the heavy gales of the past winter, and has successfully withstood the battering of the seas.

Mr. C. Ratcliff, A.M.I.S.E., M.R.San.I., Surveyor to the Swanage U.D.C., is responsible for the design and the construction of the sea wall.



No. 2 Silo, Alexandra Docks, Liverpool. *(See p. 241.)*

Reinforced Concrete Grain Silos at Alexandra Docks, Liverpool.

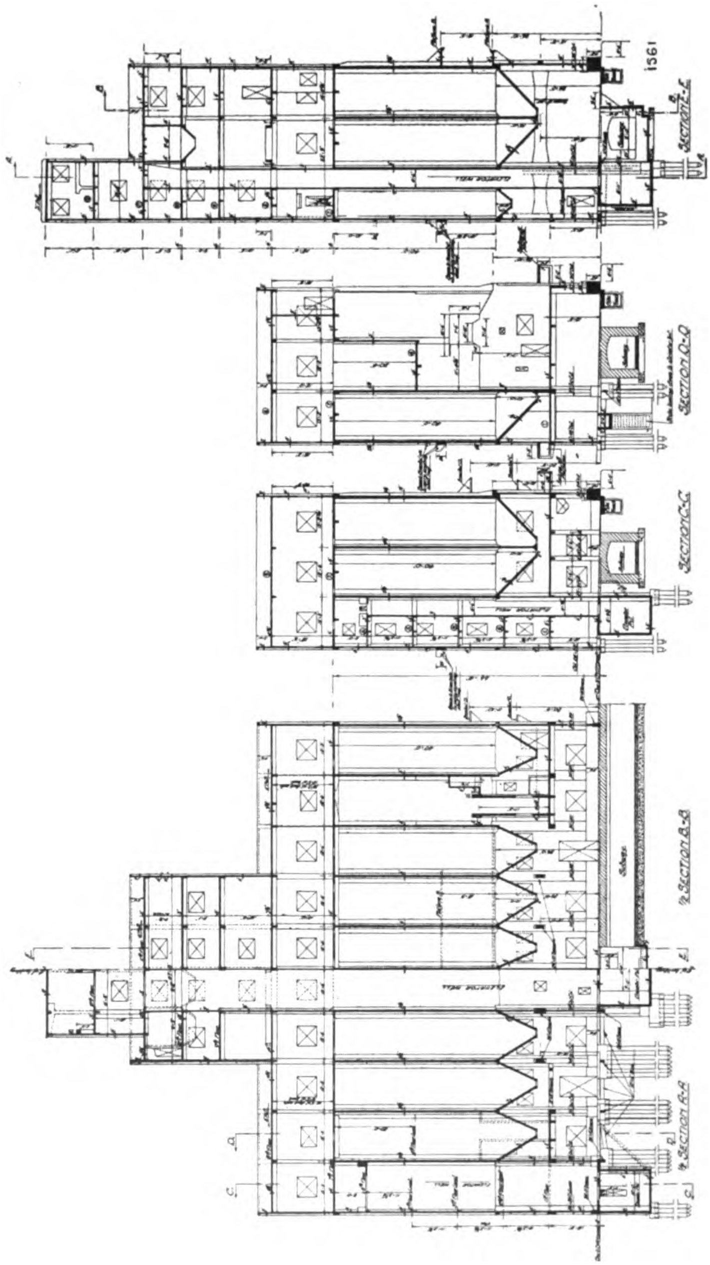
Two large grain silos at Alexandra Docks, Liverpool, have recently been completed for the Liverpool Grain Storage & Transit Co., Ltd. The structures are known as No. 1 and No. 2 Silos, with capacities of 5,500 quarters and 12,000 quarters respectively; it is the larger building (Silo No. 2) that is illustrated and described in this article. The overall height of both silos is 149 ft. 6 in.

In buildings in which the contents are extremely heavy (of which these two silos are examples) it is of very great importance that careful consideration should be given to the design of the foundations. In the case of these two buildings it was first suggested that they should be constructed on rafts, as has been the practice for other structures in the Mersey Docks, but after consideration it was decided that, owing to the possibility of unequal settlement consequent on one side of the building being supported by the dock wall and the remainder on a raft which would rest on made-up ground behind the dock wall, this method was not desirable. Had a raft been adopted the pressure on the sub-soil would have been about 2 tons per sq. ft., but as the subsoil consisted of made-up ground this pressure appeared to be rather too high; the proposal was therefore abandoned, and reinforced concrete piles were substituted.

In order to ascertain the nature of the ground trial holes were dug, and it was found that the filling consisted of well-packed clay, brick rubbish, gravel and sand, the actual rock occurring about 28–30 ft. below the made-up level. In order to decide upon the length of the piles necessary over the whole area, trial piles were driven. For this purpose a piling engine with a 2-ton monkey was used, the set decided upon being a penetration of not more than ⅞ in. for ten consecutive blows. The first 10 ft. of the drive was fairly easy, but the last 20 ft. was such as to justify the designers in considering that piles driven to this depth would be capable of withstanding any load that would be thrown upon them by the finished structure. The piles were all cast 30 ft. in length and left to mature from 6–8 weeks before driving, the concrete being a fairly rich mixture comprised of hard granite chippings from ¼ in. to ¾ in. gauge, clean sand, and Portland cement. The actual piling was carried out by means of a steam hammer.

No. 2 silo measures on plan 122 ft. 6 in. by 40 ft., and contains eighteen bins each with a capacity of 120 tons, four bins with a capacity of 100 tons each, and two bins to hold 50 tons each. The building is supported on the dock wall on the west side and on piles driven into the filling at the back of the dock wall; owing to the position of a subway the spacing of the columns supporting the structure is not symmetrical. Down the length of the building the columns are spaced at 12 ft. 6 in. centres, one row being 25 ft. from the row immediately next to the dock wall, and the next row 12 ft. 6 in. distant. The columns at the side of the building next the dock wall vary from 32 in. by 30 in. in section to 24 in. by 24 in., in accordance with the loads to be carried, the maximum load being about 280 tons. In order to distribute this load on the dock wall a reinforced concrete sleeper beam was constructed on which this row of columns rests; this beam is 3 ft. 6 in. deep, 3 ft. wide at the base, slightly tapering towards the top. By this means the load on the dock wall is reduced to about 6½ tons per square foot maximum. The total load on the dock wall from the columns on the west side is about 1,500 tons, and this additional load considerably increases the stability of the wall against the overturning moment due to the extra load on the filling from the columns at the back of the silos. This has the advantage of increasing the resistance to any forward sliding tendency, so that although the dock wall has now to resist a considerably greater pressure than was originally the case, yet by the arrangement and design of the new buildings it is really more stable now that a greater load is imposed.

As the columns on the dock wall were constructed to resist very heavy loads, great care had to be exercised in the design and detail of the reinforcement: all the vertical bars are tied in by links in



No. 2 Silo, Alexandra Docks, Liverpool: Sectional Elevation.

all directions. The external walls up to the underside of the bins are 4 in. thick stiffened by 12 in. by 6 in. horizontal beams at about 15 ft. from the ground level. From the section it will be seen that the buildings are rather narrow when their great height is considered, and owing to the exposed situation in which they have been constructed there is a considerable wind pressure to resist. The eccentricity of the total load due to the wind pressure equals approximately 2 ft., so that the columns are subjected to a bending moment in addition to the direct load, and in order to reduce this moment wind braces were introduced at a point 15 ft. from the ground level, and consist of a reinforced concrete member, 24 in. deep by 10 in. wide, haunched at each end on to the columns, together with diagonal braces 12 in. square in section.

The columns in the intermediate row are octagonal in section, from 30 in. to 34 in. between opposite faces, the bases being square in plan, and a few inches larger than the thickness of the columns. In order to obtain greater compressive strength in these columns, the concrete consists of a richer mixture than for the remainder of the building. The piles supporting the columns are 14 in. square, driven in groups of five, six, or seven, as necessary to resist the load from the columns, and are surmounted by concrete caps 42 in. thick (especially reinforced to resist the very heavy punching shear) on which the columns are supported.

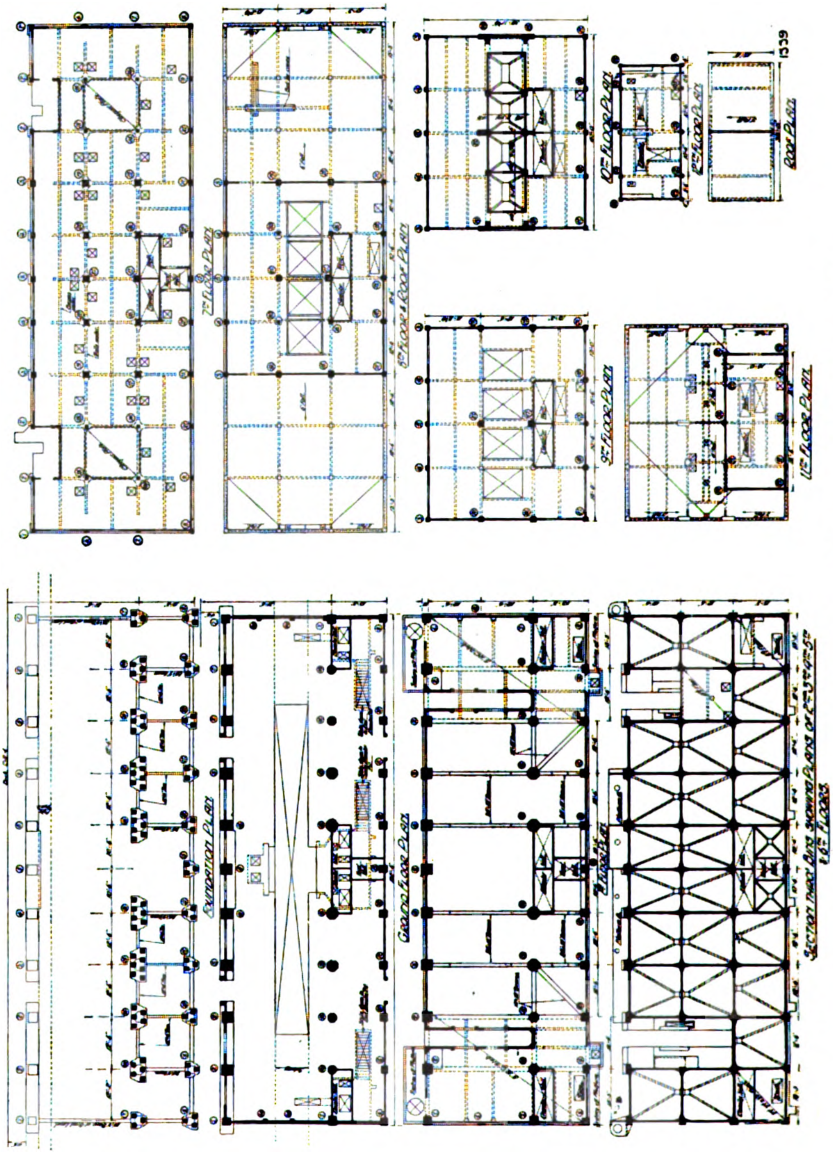
The columns in the back row are all 22 in. wide of varying thicknesses from 22 in. to 26 in., each supported by three piles 12 in. square surmounted by a cap 24 in. thick.

The external walls throughout are 4 in. thick, stiffened by braces 12 in. by 6 in. in section. "Sacking-off" floors consisting of a 5-in. reinforced concrete slab, supported on main beams, 15 in. by 14 in. and 15 in. by 12 in., and secondary beams 12 in. by 6 in. in section are constructed at each end of the building at the first floor level. Between the second and third columns on the dock front the thickness of the concrete wall is increased to 6 in. for 17 ft. of its height from the first-floor level. This portion of the wall is supported by 8-in. cross walls in the second bay of the intermediate columns and the second bay of the dock front. These walls are tied in at the bottom by the first floor, and at the top by 4 in. slabs back to the columns and bin walls. The reason for this strengthening of the exterior walls is that they support heavy lattice cantilever girders carrying the grain elevator plant. The wind pressure on the girders and elevator causes a very considerable eccentricity of the load, so that when a gale is blowing parallel to the dock face the load on one support is equal to about 37 tons while that on the other is only about 7 tons; consequently considerable torsion stress is developed in the wall and the necessary support and strengthening had to be arranged to withstand this stress. From the first floor a small iron staircase gives access to the gear and bearings of this girder, and over this staircase is a reinforced concrete hood, consisting of walls and roof 3 in. thick. At each end of the building an elevator pit is provided to accommodate the gear and motors of the elevators, which are carried up to the seventh floor. These pits consist of walls 5 in. thick, and a floor 8 in. in thickness. Owing to the close proximity of the dock water the soil surrounding these pits is to some extent waterlogged, and as it was essential that the pit should be watertight particular care had to be exercised in the design and construction of this part of the work. When finished it was found that in both cases the pits were perfectly dry.

The elevator walls extend from the top of the pits to the sixth floor, and are 3 in. in thickness, strengthened at each floor by stiffener beams. Small floors are constructed between the elevator walls and back wall at the second, third, fifth and sixth floors. These are all 4 in. thick, and carried by 9 in. by 4 in. rimmer beams, which also support the staircase openings.

Adjoining the north elevator a hoist well has been constructed up to the eleventh floor: this well has walls 5 in. in thickness on one side and 4 in. on the other three sides, which walls also form the face of some of the smaller bins.

At the first floor level on the east wall are two small projecting sack delivery platforms for loading-out sacks, consisting of 3½-in. slabs cantilevered from the walls by means of dwarf walls around the platform, strengthened by a plinth and coping. At each end on the front wall facing the dock the first floor has been



No. 2 Silo, Alexandra Docks, Liverpool: Sectional Plans.

cantilevered out, and a small balcony constructed with dwarf walls, plinth and copings similar to those on the east walls. Openings are arranged in the floors of these balconies for suspending swivelling shoots for loading sacks out to barges or vessels.

Two balconies are also arranged on the wall next the dock, and are carried by brackets built out from the front row of columns. They are arranged to support four swinging steel frames which carry the shoots delivering grain in bulk from the elevator tower to barges or vessels in the dock. The lower balconies are 26 ft. 6 in., and the upper balconies 39 ft. 3 in., above dock sill level. The platforms are 4 in. in thickness, and the supporting brackets are 3 ft. 6 in. deep by 4 in. thick, the reinforcement being well anchored back to the bin walls and the main columns. At the north-west and south-west corners small platforms are built by brackets from the corner columns and the bin walls, for carrying the steel crane frames for hoisting sacks from barges or vessels in the dock and also for supporting shoots for loading out bulk grain to the dock.

Owing to the position of the discharge mouths, the design and detail of the hopper bottoms is somewhat complicated. It will be seen from the section that only three of the sides are sloped down to form the hopper bottom, the remaining wall being carried down vertically and tapered in order to meet the intersection of the other sides. The positions of the mouths are, therefore, eccentric, and in consequence the tension on the larger sloping face of the hoppers is more than on the other two faces. This is more noticeable when the bins are emptying, as, owing to this eccentric position of the mouth, the bottom pressure varies considerably. The long slope of the hoppers is 6½ in. in thickness, and the shorter 6 in.

Owing to the friction on the walls from the grain, the lateral and vertical pressures are considerably reduced, but even taking this reduction into account the load on the hopper bottoms is very considerable. The bin walls are 5½ in. thick generally, but those which span over 25 ft. are increased to 6 in. in thickness, reinforced horizontally to take the lateral pressure from the grain.

The division walls between the bins are reinforced on both faces so as to make allowance for either bin being full when adjoining bins are empty. The walls are thickened at the corners to increase the resisting moment when the bending moment is at its maximum and to take the column loads from above.

Above the opening for the elevator girder is a dust chamber consisting of a 4-in. floor and walls supported on beams 12 in. by 5 in. in section, window openings being left in the wall slabs. Above the bins at the seventh floor level a floor is provided to support the conveyor bands. This floor consists of a 4-in. slab supported by the bin walls and 12 in. by 6 in. beams across the middle of the bins. Openings for the conveyor shutes are arranged over each bin, special trimmer bars being built in the slabs to stiffen the edges. Fifteen feet above the tops of the bins a slab extends over the whole of the structure, part acting as a roof and the remainder as a floor. This is supported on main and secondary beams, carried on columns 9 in. square, the columns being supported by the bin walls. The roof slab is 4 in. thick, and is laid to a fall of 6 in. towards the dock front, so as to drain rainwater into the dock.

A parapet, 3 in. thick and 3 ft. high, with a 9 in. by 6 in. coping, is constructed round the roof. At the seventh floor level a 12 in. by 12 in. stiffener beam has been constructed between the columns. The eighth floor, which is immediately under the weighers, consists of a slab 4 in. and 3½ in. thick, supported by 12 in. by 5 in. beams on columns 14 in. to 16 in. square in section resting on the bin walls. Special reinforcement was designed for the openings in this floor, through which the steel hoppers from the weighers above project.

The ninth floor was designed for an ordinary floor load, in addition to the various loads from the weighing machines, and consists of a slab 3½ in. to 4 in. thick supported on main and secondary beams from 14 in. by 6 in. to 10 in. by 5 in. in section on columns 12 in. square.

The tenth floor consists of a slab 3½ in. thick, supported on main and secondary beams. Between this floor and the roof are four reinforced concrete hoppers, each to contain 16 tons of grain. The external walls of these hoppers are 4½ in. thick, and the division wall 6 in. The hoppers are carried by beams 18 in. by 14 in. in section, supported by the external columns, and are also slung up by means of the reinforcement on the top of the walls.

The roof at the eleventh floor level is from 3 in. to 3½ in. thick, similarly supported to the floor below. A parapet wall extends round this roof, similar to that on the roof at the lower level. The elevator tower is carried up to two stories higher, the external walls being 4 in. thick, stiffened by vertical columns 12 in. by 10 in. in section and stiffener beams; a roof 4 in. thick and spanning 14 ft. is constructed over the tower.

The engineers in charge of the work were Messrs. Spencer & Co., of Melksham. The reinforced concrete design is by the Indented Bar & Concrete Engineering Co., Ltd., and the contractors Messrs. Wilson Lovatt & Sons, Ltd., of Wolverhampton, who have carried out many important reinforced concrete works in the country, including transit sheds, coal bunkers, grain silos, jetties, wharves, factories, reservoirs, etc. At present the firm is interested in the construction of *in situ* concrete houses, of which they are building one thousand for the Liverpool Corporation.

Size and Shape of Test Specimens.

DATA of interest to those engaged in the testing of concrete will be found in Bulletin 16 of the Structural Materials Research Laboratory, Lewis Institute, Chicago, entitled "Effect of Size and Shape of Test Specimen on Compressive Strength of Concrete" by Mr. Harrison F. Gonnerman. The report is reprinted from the 1925 *Proceedings* of the American Society for Testing Materials.

Tests were made on 1755 concrete specimens at ages of 7 days to 1 year in a study of the compressive strength of:

(1) Cylinders 1½ in. to 10 in. in diameter, 2 diameters long,
(2) Cylinders 12 in. long, 3 in. to 10 in. in diameter,
(3) Cylinders 6 in. in diameter, 3 in. to 24 in. long,
(4) Cubes, 6 in. and 8 in.,
(5) Prisms, 6 in. by 12 in. and 8 in. by 16 in.

The relative strength of the different forms of specimen was compared with the strength of 6-in. by 12-in. cylinders from the same concrete.

The principal conclusions are:

(1) The 6-in. by 12-in. cylinder generally used for compression tests of concrete as recommended by the American Society for Testing Materials, is a satisfactory form of specimen. However, this size of cylinder should be limited to aggregates not larger than 2 in. in diameter. Cylinders 4 in. by 8 in. or 5 in. by 10 in., are suitable for the smaller sizes of aggregate. The ratio of diameter of cylinder to maximum size of aggregate should not be less than about 3. For aggregates larger than 2 in., 8-in. by 16-in. cylinders or larger should be used.

(2) For cylinders of length equal to 2 diameters, lower strengths were generally obtained with the larger cylinders. The decrease in strength with size of cylinder was not important for diameters of 6 in. or less; 8-in. by 16-in. and 10-in. by 20-in. cylinders gave 96 per cent. and 92 per cent. of the strength of 6 by 12-in. cylinders.

(3) Concrete cylinders having a ratio of length to diameter of from 0·5 to 4·0 gave the following average strength-ratios at 28 days:

Ratio of length to diameter, 0·5, 1·0, 1·25, 1·5, 2·0, 3·0, 4·0.
Strength-ratio, percentage of strength of 6-in. by 12-in. cylinder, 178, 115, 107, 103, 100, 95, 90.

These strength-ratios agree with those reported by other investigators. The difference in strengths of cylinders having ratios of length to diameter between 1·5 and 2·5 was not important.

(4) The 6-in. and 8-in. cubes tested at ages of 7 days to 1 year gave strengths averaging 18 per cent. and 13 per cent. higher than 6-in. by 12-in. cylinders. The strengths for 6-in. by 12-in. and 8-in. by 16-in. prisms were lower at all ages than for 6-in. by 12-in. cylinders; the strength-ratios averaged 93 per cent. and 91 per cent. respectively.

(5) For all forms of specimens the compressive strength increased with age for moist curing. For cylinders and prisms of length equal to twice the diameter or width, the 7-day, 3-months and 1-year strengths averaged 52, 142 and 178 per cent. of the 28-day strength for 1·5 concrete. The corresponding percentages for 6-in. and 8-in. cubes were 60, 129 and 165 per cent.

The Strengthening of Bridges.

At a recent conference of the Institution of Municipal and County Engineers, Mr. C. G. Mitchell, B.Sc., A.M.Inst.C.E., and Mr. C. S. Chettoe, B.Sc., A.M.Inst.C.E. (both of the Roads Department of the Ministry of Transport) dealt with the subject of the strengthening of existing bridges by the use of reinforced concrete.

Brick and masonry arches were the types chiefly dealt with, and the paper stated that the best method of strengthening the arch ring was generally to construct a plain or reinforced concrete relieving arch above the existing arch ring. This relieving arch should be given a good bearing on the old abutments, as shown in *Fig.* 1. It would, of course, be necessary to investigate the strength of the abutments to discover whether they were capable of withstanding the additional thrust. In structures of the arch type, in which rise, span and loading were constant and the moment of inertia of the cross-section was constant throughout, the ring deflections at similar points were inversely proportional to the modulus of elasticity × the moment of inertia. Hence, if deflections were the same the loadings on the arches would be directly proportional to $E \times I$. In brick arches I was constant throughout the ring, and it would in most cases be constant throughout the relieving arch. The two would be in contact, so that deflections would be the same in both. Rise and span also would be approximately the same, so that

$$\frac{\text{load taken by old arch}}{\text{load taken by relieving arch}} = \frac{E \times I \text{ (old arch)}}{E \times I \text{ (relieving arch)}}$$

From this the approximate required dimensions of the relieving arch could be obtained. The existing arch would carry the dead load of the relieving arch in addition to its own weight. If the existing abutments were not strong enough to take any extra thrust and a relieving arch was constructed without abutment (*Fig.* 2), this would act merely as a slab except for friction between it and the old arch, and as it would take but little load on itself was not recommended.

A method which had been adopted where it was not desired to put further stresses on the abutments was shown in *Fig.* 3. Unless the material AA between slab and arch ring was so consolidated as to be practically as rigid as the slab itself the effect of this would be to concentrate nearly all the live and dead load carried by the slab on the crown of the arch, further increasing the bending moment at the crown ; so that the method had its dangers. It would be better to fill up below the slab on each side with plain concrete as shown in *Fig.* 4, the centre B being filled with earth. This arrangement might be of use where the span of the arch was small and abutments very weak, as the slab would transfer the loading to the arch haunches and would at the same time act as a tie.

Where the arch was of fair size and the abutments were insufficient to take the additional thrust of the relieving arch, it was better if possible to strengthen the abutments. Tie rods at the level of the springings were generally impracticable or unsightly. Sometimes where headroom and cross-sectional area of opening were unimportant the relieving arch might be constructed within the existing one, the abutments being thickened inwards at the same time (*Fig.* 5). The objection here was that it was difficult to place the concrete of the relieving arch satisfactorily and also to ensure contact between relieving and existing arch when the centering was removed. Also, the old ring would carry the entire dead load except that of the new ring.

Sometimes cracks more or less parallel to the centre line of the roadway appeared in the arch ring due to spreading of the spandrel walls. The vault might then be tied together by transverse rods and plates, there being a rod above the extrados and one below the intrados to each pair of plates. A more satisfactory method where a relieving arch was employed and the spandrel walls were taken down and rebuilt would be to turn down the relieving arch (which must have good transverse reinforcement) well into the old arch ring (*Fig.* 6). Cracks in the old arch ring would, of course, be grouted up.

In the case of multiple-span bridges, particularly old bridges, the vault might be strengthened by backing it up deeply over the haunches, even up to the road

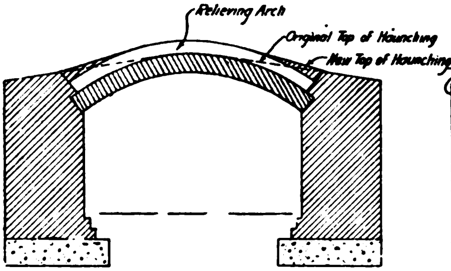


FIG 1.

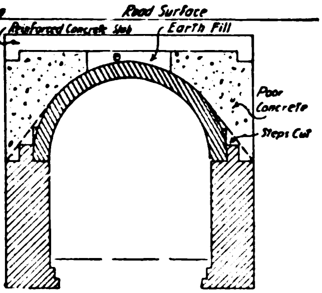


FIG 4

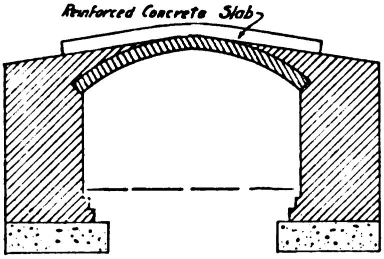


FIG 2.

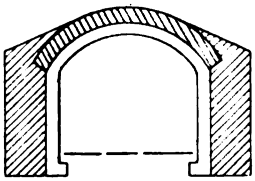


FIG 5

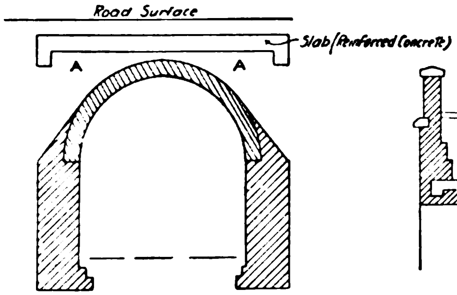


FIG 3.

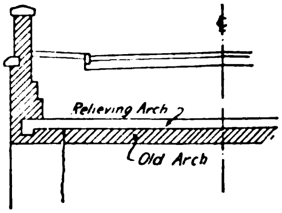
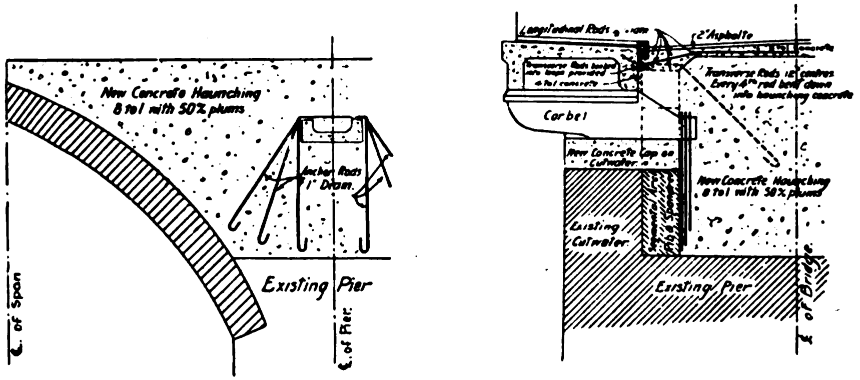


FIG. 6.

The Strengthening of Bridges.


New Concrete Haunching 8 to 1 with 50% plums
Anchor Rods 1" Diam.
Existing Pier
℄ of Span
℄ of Pier
Longitudinal Rods
2" Asphalte
Concrete
Transverse Rods looped into loops provided
4 to 1 concrete
Transverse Rods 12" centres Every 4th rod bent down into haunching concrete
Corbel
New Concrete Cap on Cutwater
New Concrete Haunching 8 to 1 with 50% plums
Existing Cutwater
Existing Pier
℄ of Bridge

Longitudinal Section. Through Corbel

Cross Section on Centre Line of Pier.

FIG 7

formation, as in the case of Bideford Bridge (*Fig.* 7). The extra depth over the haunches, as in this case, might prove useful as a foundation or anchor for cantilevers carrying a footway or footways.

A few bridges had been constructed without filling, but with a series of parallel spandrel walls. These supported stone slabs, on which the roadway was carried (*Fig.* 8). Stresses in such a bridge were more or less indeterminate, and a relieving arch could not be employed for strengthening without removal of the internal spandrel walls. In most cases it was desirable to remove these internal walls, construct a relieving arch, strengthen the outer spandrel walls and fill the spandrels.

If possible, abutments were best strengthened by excavating at the back in sections and thickening with mass concrete. Buttresses might be employed as an alternative. If spreading had occurred due to settlement of one or both abutments it was often possible to check this by the construction of ties formed of

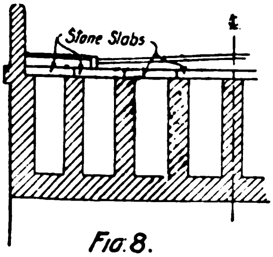


FIG. 8.

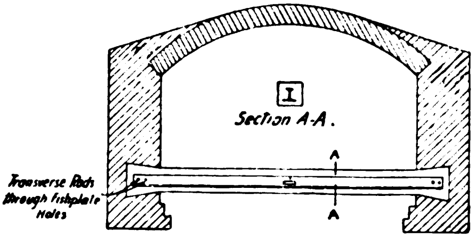


FIG 9

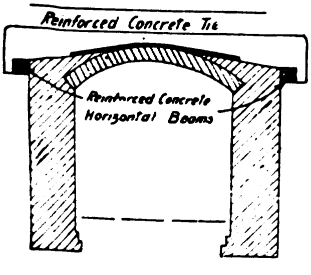


FIG. 10

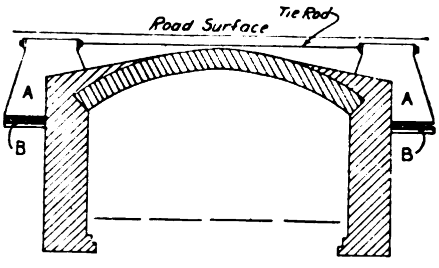


FIG 11

old steel rails securely anchored into the abutments below stream bed level. The ties could be surrounded with concrete (*Fig.* 9). It might occasionally be possible in the case of flat arches, where thickening of the abutments was difficult or costly, to strengthen the latter by the introduction of reinforced concrete ties above and distinct from the arch ring. Heavy point-loads should be prevented from coming on these ties. Such ties, which would be subjected to bending, should be constructed under the footways, and their ends would be united by reinforced concrete beams (*Fig.* 10). They should not be monolithic with the arch ring.

Where the carriage-way was of fair width ties beneath the footways might not be sufficient. A suggestion for such a case was shown in *Fig.* 11. Steel tie rods connecting reinforced concrete blocks AA could be employed, and might be conveniently spaced beneath the carriage-way. The blocks could be pre-cast, and pre-cast reinforced concrete slabs BB would be dropped in between them. The weight of the filling above these slabs would counteract the moment produced by the pull of the tie-rods. The filling behind the blocks and slabs should be well consolidated and the rods given some initial tension.

Another method was to anchor the blocks by steel rods into holes drilled vertically into the abutments; after the insertion of the rods the holes would be grouted up.

The strength of abutments was naturally influenced by the width of the bridge if the latter possessed substantial wing walls. In a narrow bridge a considerable proportion of the thrust was probably taken by the wing walls.

Many old bridges had been found when examined to be practically without abutments, yet had stood up to modern traffic. A new bridge of the same dimensions would fail, as the backing of its abutments would be unconsolidated whereas the backing of the old bridge would have been converted by years of traffic into a mass nearly as rigid as the abutments themselves.

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

Curing Rapid Hardening Portland Cement Concrete.

Question.—I observe that in the interesting lecture by Major Smith, given in your last issue, it is stated that when using rapid-hardening Portland cement no further curing was necessary after 24 hours in ordinary weather, or 3 days when temperatures were very low. Is it correct to infer from this that from every point of view the curing of rapid-hardening Portland cement concrete can be considered complete, under the worst conditions, in 3 days? I have hitherto had the impression that at least 10 days' curing of all Portland cement concrete was desirable.—P.

Answer.—With reference to your correspondent's letter, there is some misapprehension as to the curing period for rapid-hardening Portland cement concrete. The statement referred to by your correspondent was in connection with an argument depending upon the development of strength in the concrete, and in this particular connection the statement is correct. At the same time, however, it is undoubtedly true that curing under damp conditions for a period of 10 days is desirable with rapid-hardening Portland cement concretes, as well as other Portland cement concretes, because the hydration of the chemical compounds in the cement is proceeding at a rapid rate during this period, and the presence of moisture is necessary for this hydration to proceed satisfactorily. Hence, although the concrete is mature enough to resist expansion and contraction in 1 to 3 days, depending on the weather, yet to enable the concrete to develop its maximum strength, the curing under damp conditions should be maintained for 10 days.—R. A. B. Smith.

REINFORCED CONCRETE WHARF ON THE MANCHESTER SHIP CANAL.

Many interesting features, adopted with a view to keeping the cost as low as possible, were introduced in the construction of the Trafford Wharf on the Manchester Ship Canal, which is fully illustrated in this issue. The construction of the wharf was carried out by Messrs. Kirk and Randall, Ltd., of 146 Grosvenor Road, London, S.W.1, to the designs of Mr. H. A. Reed, Chief Engineer of the Manchester Ship Canal Company, and the work has just been completed.

The wharf is built entirely of reinforced concrete, and the extensive use of precast members is one of the most interesting features of the work, which in addition to the actual wharf on the Canal, comprises foundations for warehouses on the area between the Canal and Trafford Wharf Road.

A double length of pre-cast reinforced concrete boxes, mounted on two rows of reinforced concrete cylinders sunk in the slope of the bank and resting on the bed of the canal, was used for the construction of the wharf.

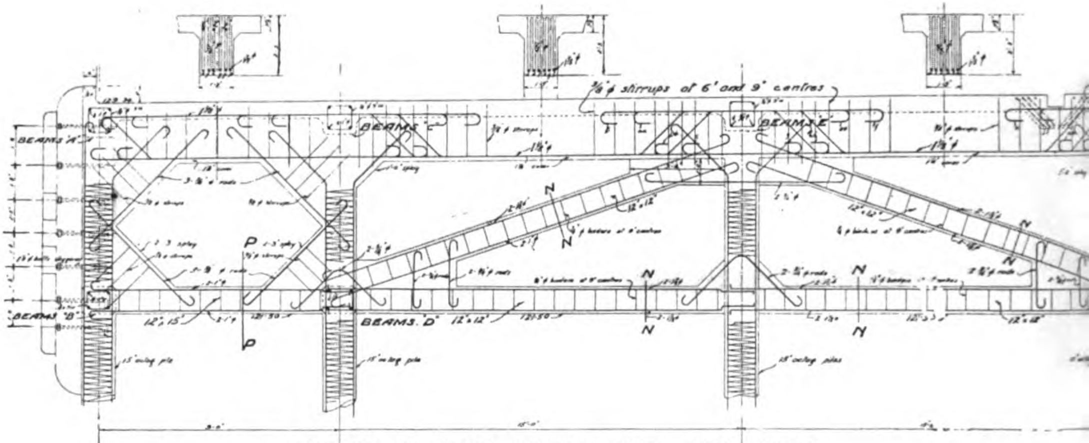
The cylinders in the outer line are 6 ft. 6 in. in diameter and approximately 28 ft. long with a thickness of wall of 4½ in., while the inner row are 9 ft. diameter, from 12 ft. to 17 ft. long, and 6 in. thick. These cylinders were constructed on the land beside the wharf, and placed by crane. Reinforcements were erected around an inner form, and outer shell forms made of $\frac{1}{16}$-in. plate stiffened by angle-iron rings were placed around in lengths of 3 ft. to 4 ft. and spaced to admit of the desired thickness of the wall. After the forms were built up, concrete was poured in until the required height for the cylinders was obtained. Subsequently the cylinders were stripped of their forms and left to mature before being placed in position by the operation of a crane.

Prior to the cylinders being put in place, a level bed was prepared for them below the water by the use of a grab, and a group of cruciform steel piles was then driven into the bed. The cylinders were lowered over the steel piles and kept concentric on them by steel guides attached by a diver. Before the cylinders were actually lowered a temporary steel dam was fitted round the top of each, as otherwise they would be completely covered by the water. When they were finally centred and levelled the cylinders were sealed with concrete, after the setting of which they were pumped out and filled solid with concrete. The tops were made level and ready to carry one end of the pre-cast reinforced concrete boxes forming the superstructure of the wharf.

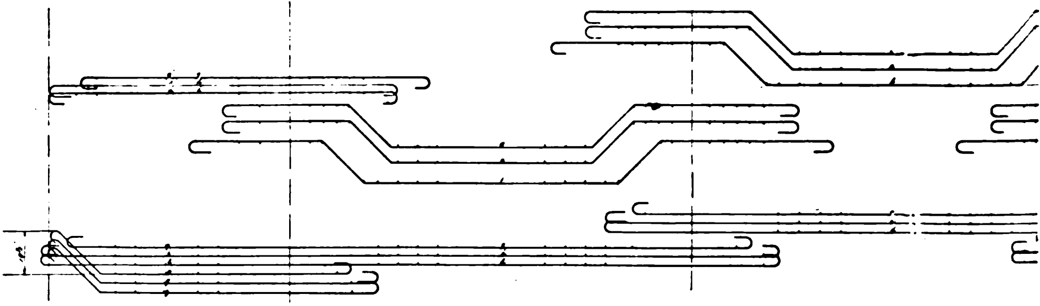
After the work on the cylinders was completed, the heavy pre-cast boxes were

Steel Forms made up ready for Concreting Foundations.

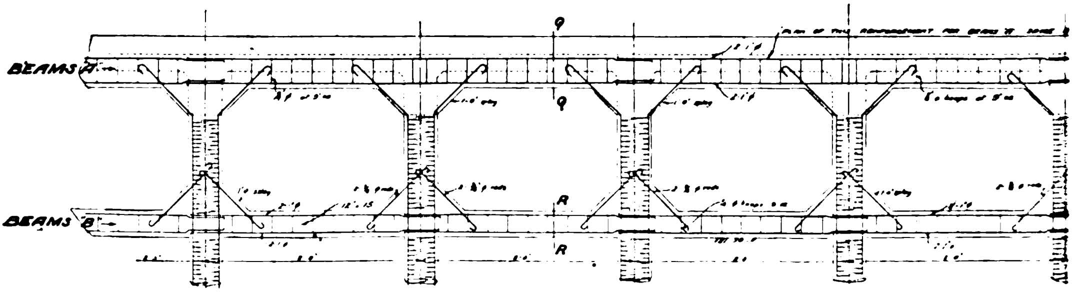
REINFORCED CONCRETE WHARF.



ELEVATION OF FRAME, SHEWING MAIN DECK BEAMS.



DETAILS OF RODS IN MAIN DECK BEAMS.



FRONT ELEVATION OF WHARF SHEWING REINFORCEMENT OF BEAMS 'A' and 'B'

Reinforcement o

REINFORCED CONCRETE QUAY AT TRAFF

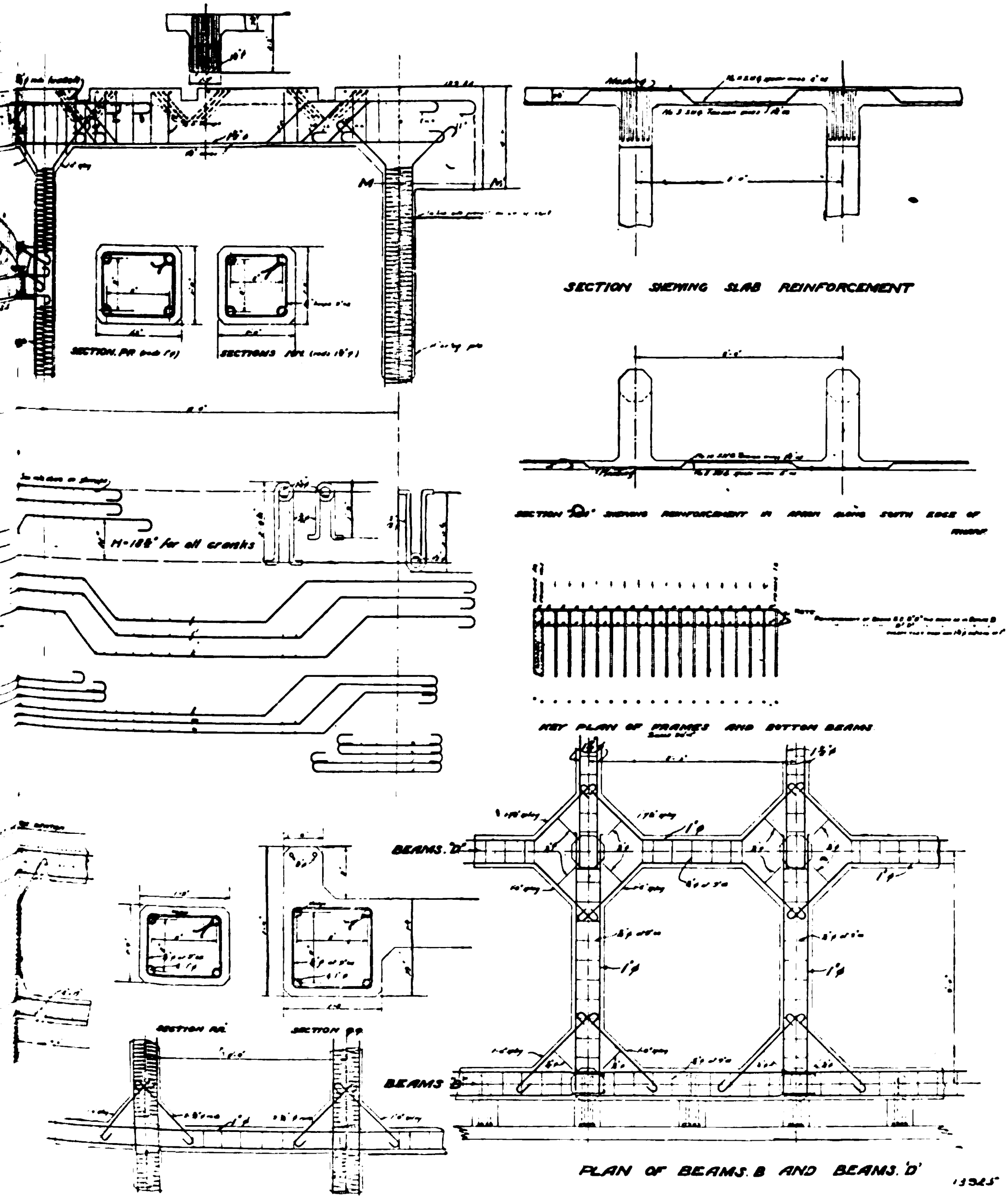
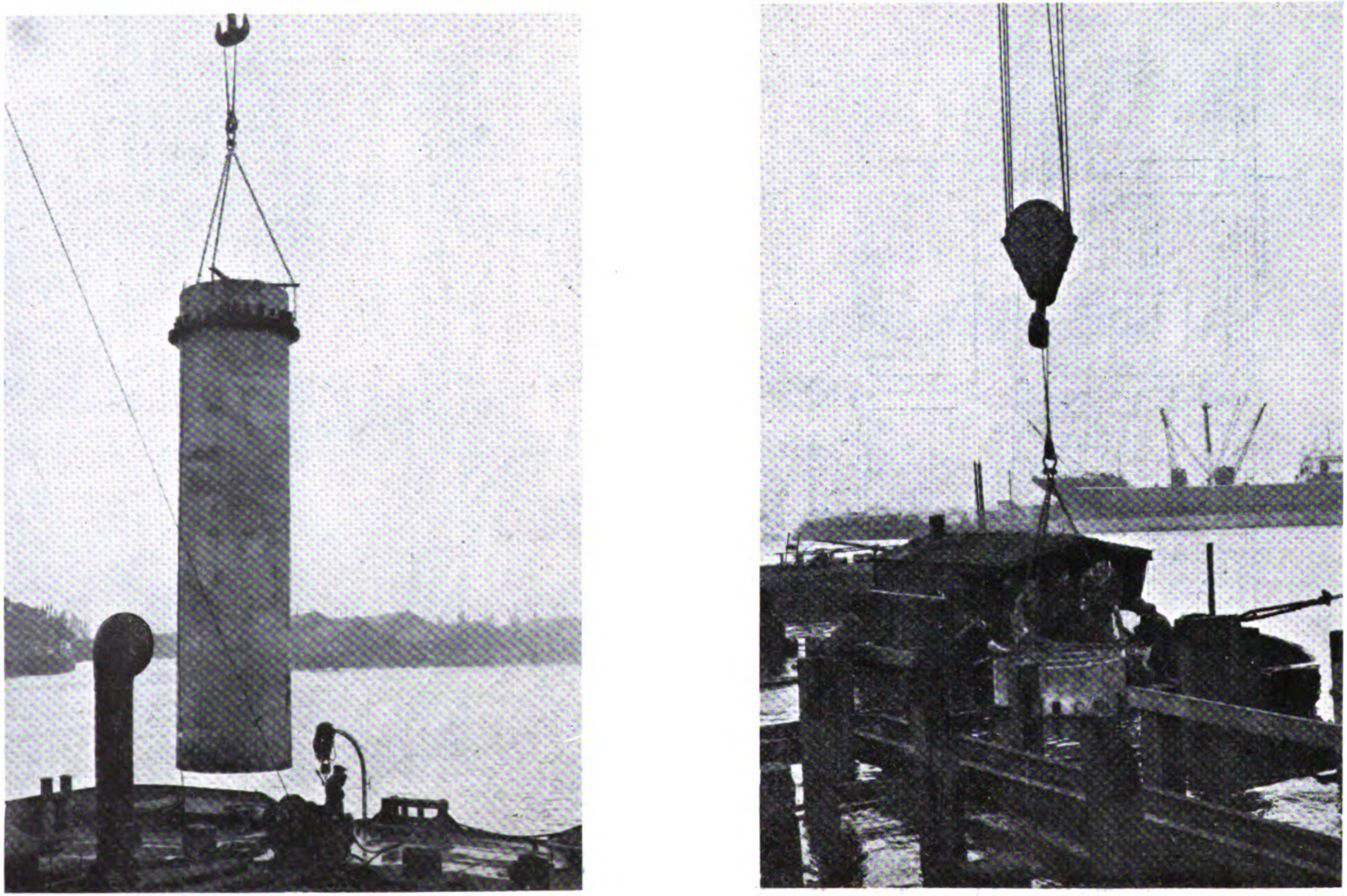

SECTION SHEWING SLAB REINFORCEMENT
SECTION P.P
SECTIONS NN
M
M=18" for all cranks
SECTION "AA" SHEWING REINFORCEMENT IN APRON ALONG SOUTH EDGE OF WHARF
KEY PLAN OF FRAMES AND BOTTOM BEAMS
BEAMS 'D'
BEAMS 'B'
SECTION RR
SECTION PP
ELEVATION OF BEAMS 'D'
PLAN OF BEAMS B AND BEAMS 'D'
13525

Plate No. 1.

D WHARF, MANCHESTER SHIP CANAL.



TRANSPORTING A 14-TON CYLINDER (28 FT. LONG BY 6 FT. 6 IN. DIAMETER).

PLACING A 6 FT. 6 IN. CYLINDER.

REINFORCED CONCRETE QUAY AT TRAFFORD WHARF.

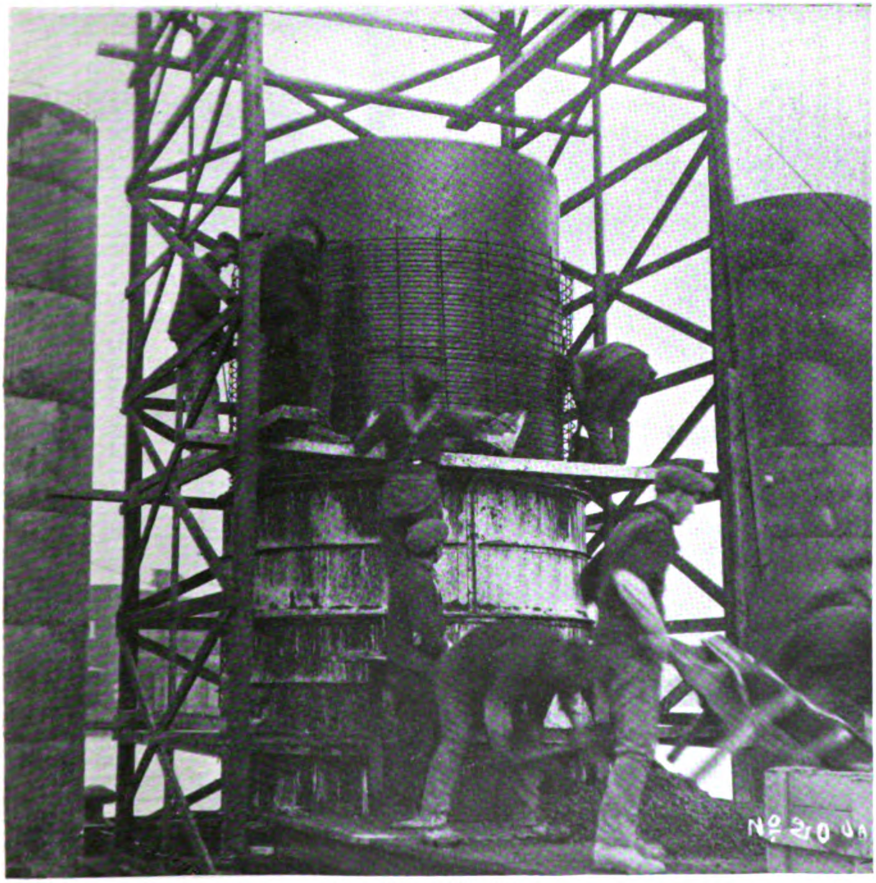
lowered into position on them by the crane as shown. A steel frame structure was built up for use in handling the castings and setting them in place.

The boxes have internal ribs and stiffeners. The reinforcements were bent to form and erected around steel forms. The projecting steel bars on the land side of the structure were later cast into other concrete work connecting the boxes. When everything was completed the outer forms were built up, leaving the width necessary for the concrete.

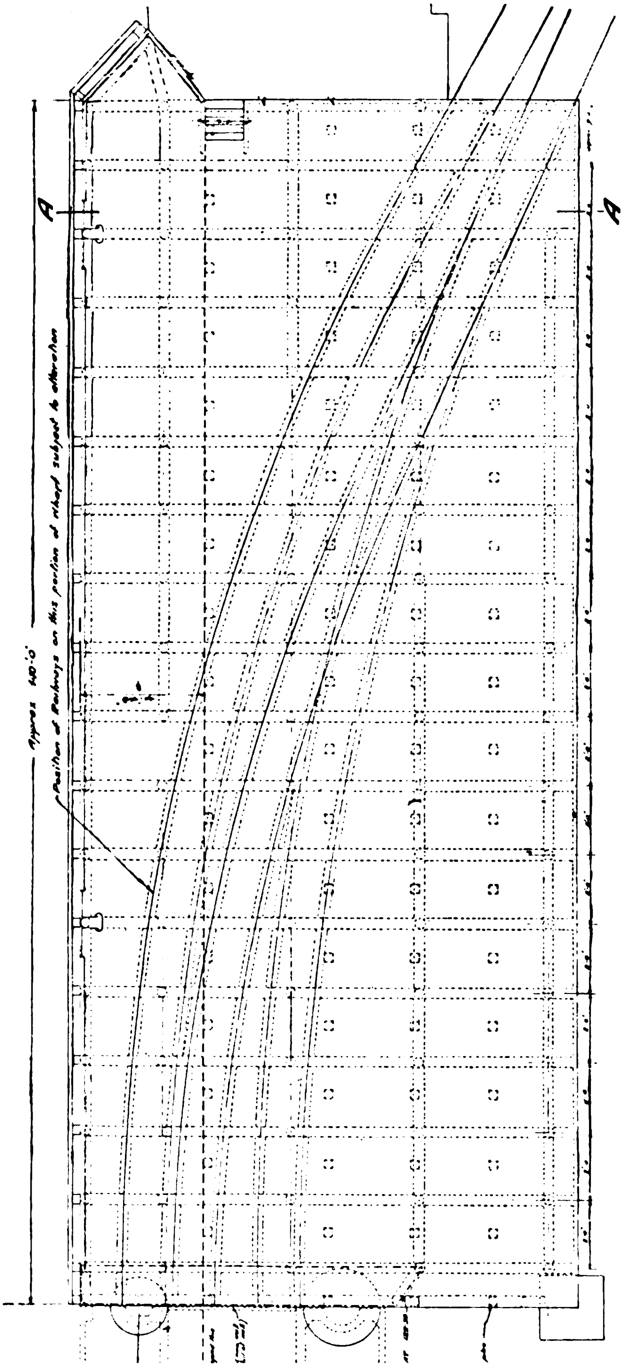
The concrete used had an aggregate of Welsh granite broken to pass through a ¾-in. mesh and Mersey sand, and was mixed by two concrete mixers, each having a capacity of ½ cub. yard and driven by a petrol engine.

An "Insley" tower mounted upon rails and of sufficient height to command the full width of the works was used to distribute the concrete. The tower was built on the works to the designs of Messrs. Cowan Hulbert. The tower was served by a travelling jib crane which transferred the materials from railway wagons to the receiving hoppers, from which it was passed to the mixers by gravity. A long chute swung from a hinged arm or jib directed the concrete to the work. This chute could be swept round with a radius of 90 ft., and thus was sufficient to serve the outside line of cylinders as well as the whole width of the transit shed foundations.

After the concrete boxes had matured they were stripped of their internal and external steel forms and left on their

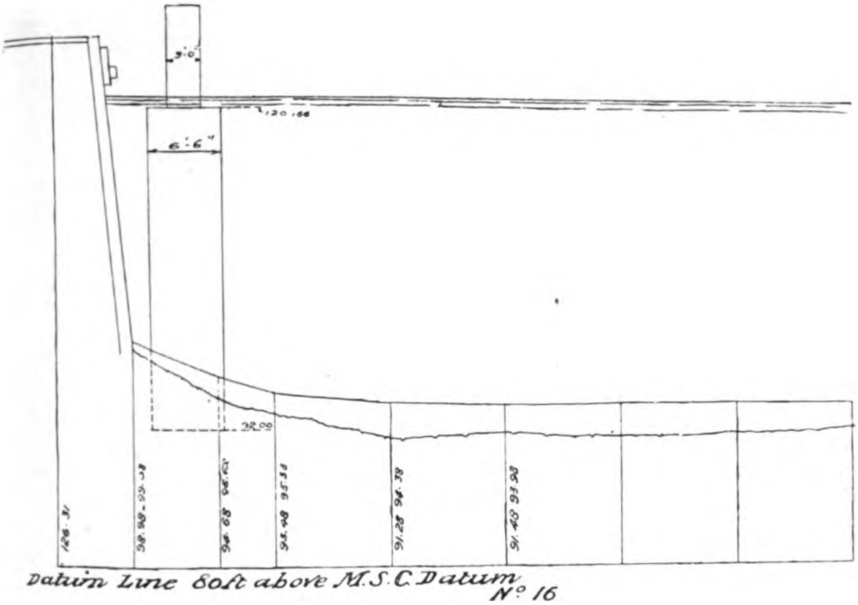


Casting 9-ft. Cylinders.

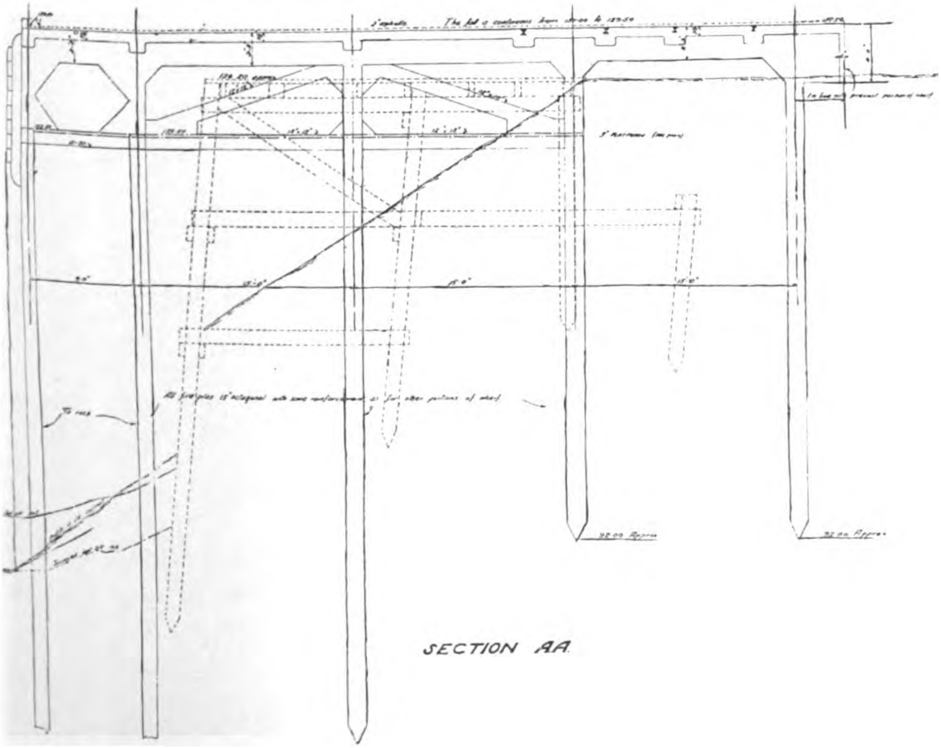

Approx 140·0'
Position of Railways on this portion of Wharf subject to alteration
A
A

Plan.

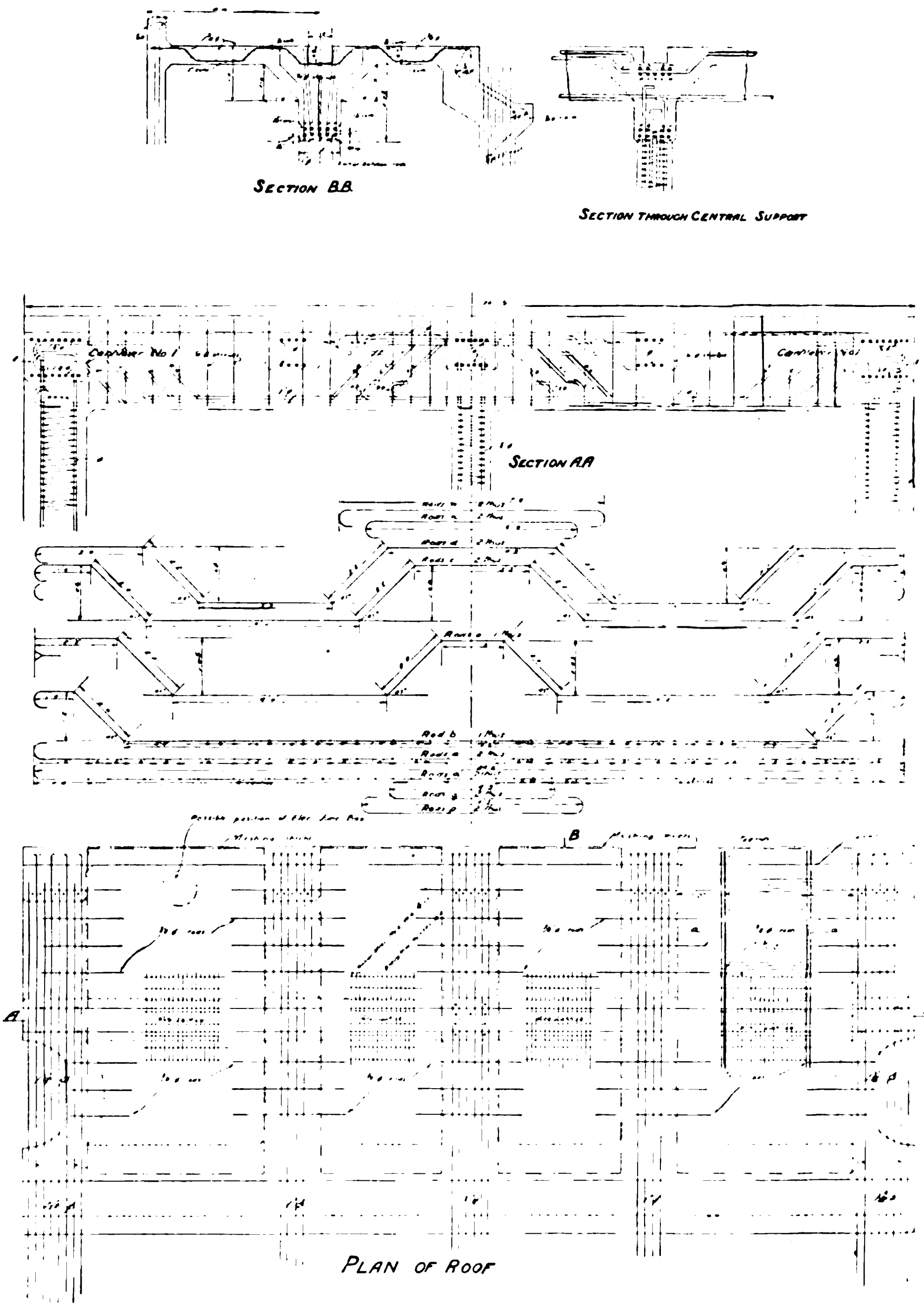
REINFORCED CONCRETE QUAY AT TRAFFORD WHARF, MANCHESTER SHIP CANAL: PILED PORTION AT EAST END.



Cross Section at East End, showing Front Cylinder.



Section.
REINFORCED CONCRETE QUAY AT TRAFFORD WHARF:
PILED PORTION AT EAST END



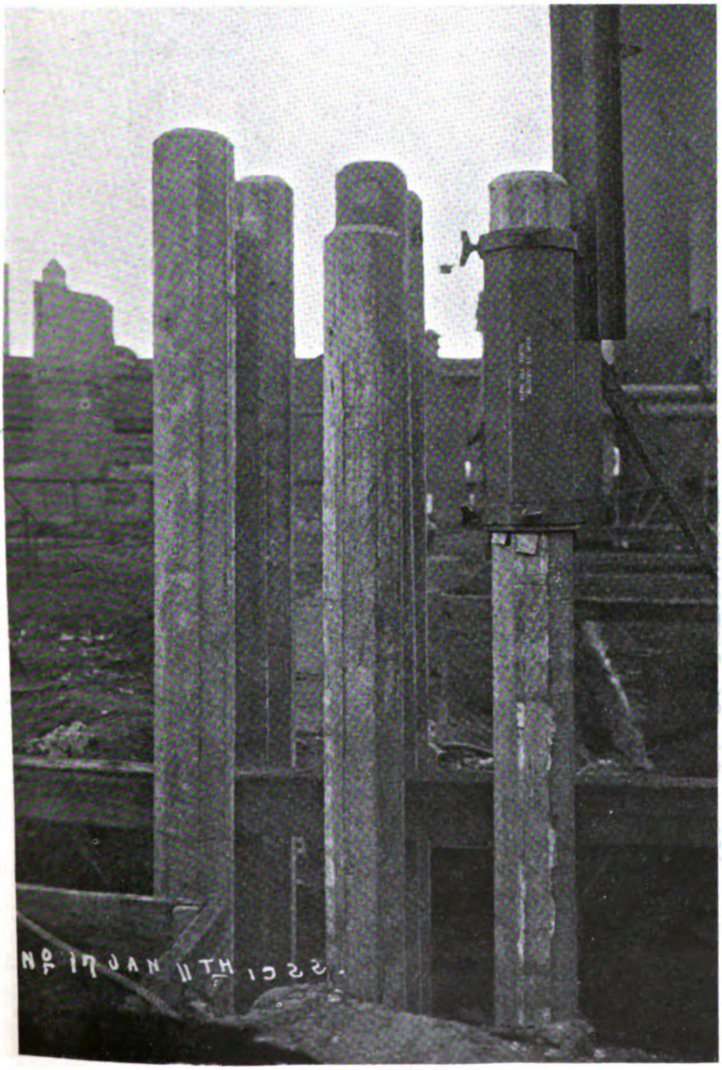
DETAILS OF T-BEAM AND ROOF.

timber bases until they were placed in permanent position upon the cylinders. The boxes are 25 ft. long, 11 ft. wide, and 9 ft. high. Each of the outside boxes weighs 67 tons and the inside boxes 62 tons.

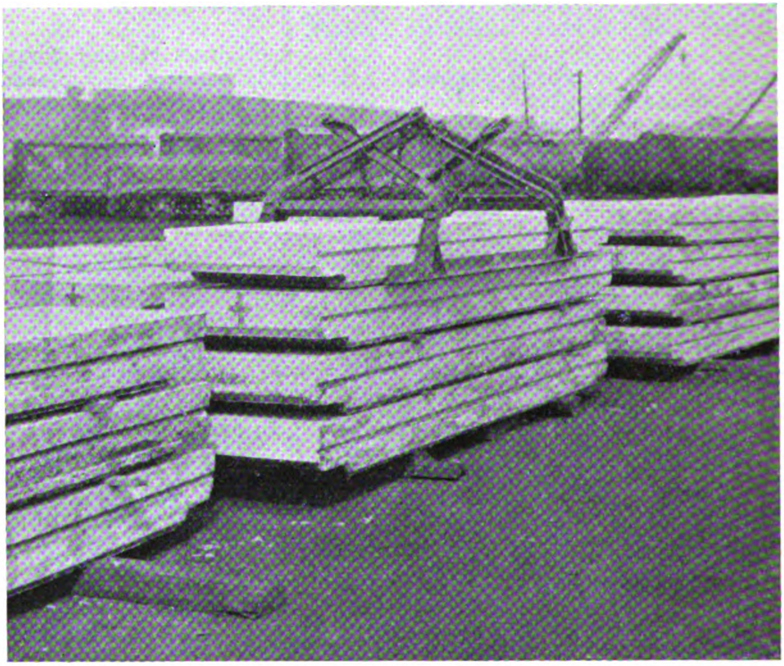
The casting operations were performed opposite the positions the boxes were to occupy in the completed wharf to obviate unnecessary handling, and were lifted into position by a specially designed 70-ton derrick crane. The pre-cast boxes were connected longitudinally and vertically to the base cylinders by reinforced concrete keys extending from the interior of each cylinder to the surface of the wharf.

The continuous subway through the outer structure will accommodate the electric cables, water mains, etc.

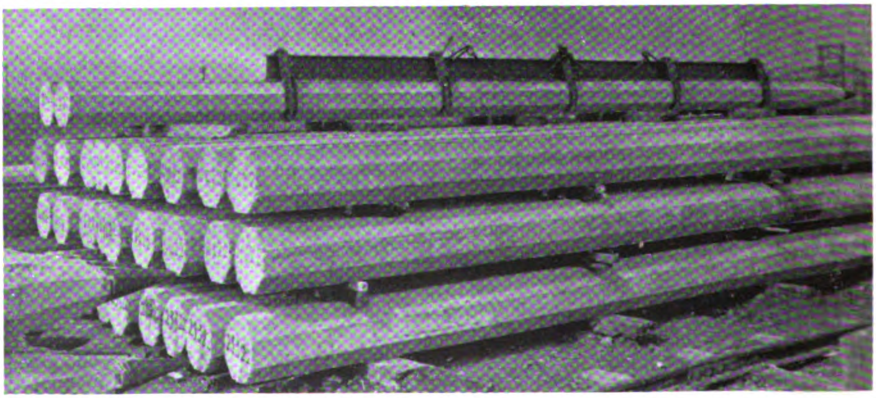
Between the outer and inner rows of boxes a passage has been built for the accommodation of the conveyor belts, which will enable the grain cargoes to be



Adapted Leaders on Pile Ready for Driving.

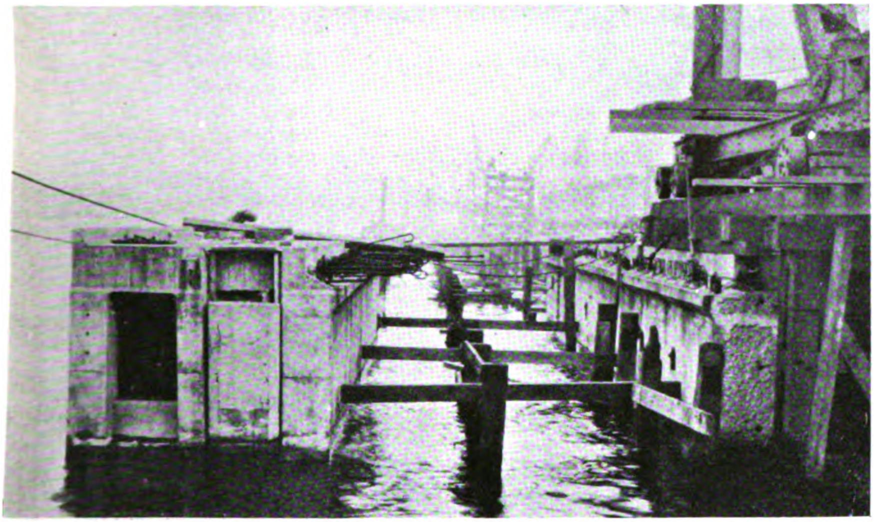


Appliance for Lifting Pre-Cast Units (Patent applied for by Kirk & Randall, Ltd.).

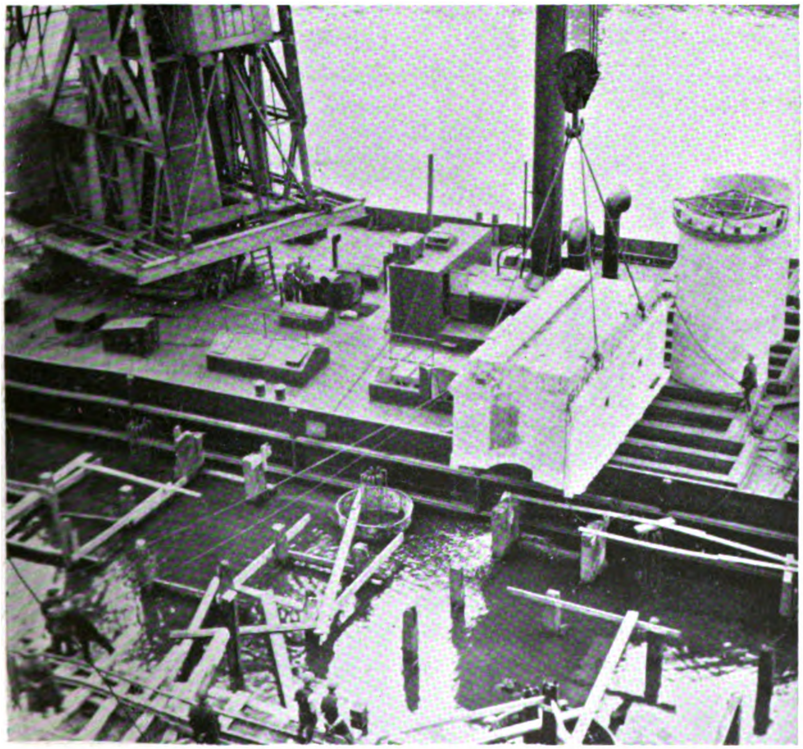


Appliance for Lifting Piles (Patent applied for by Kirk & Randall, Ltd.).

REINFORCED CONCRETE QUAY AT TRAFFORD WHARF.

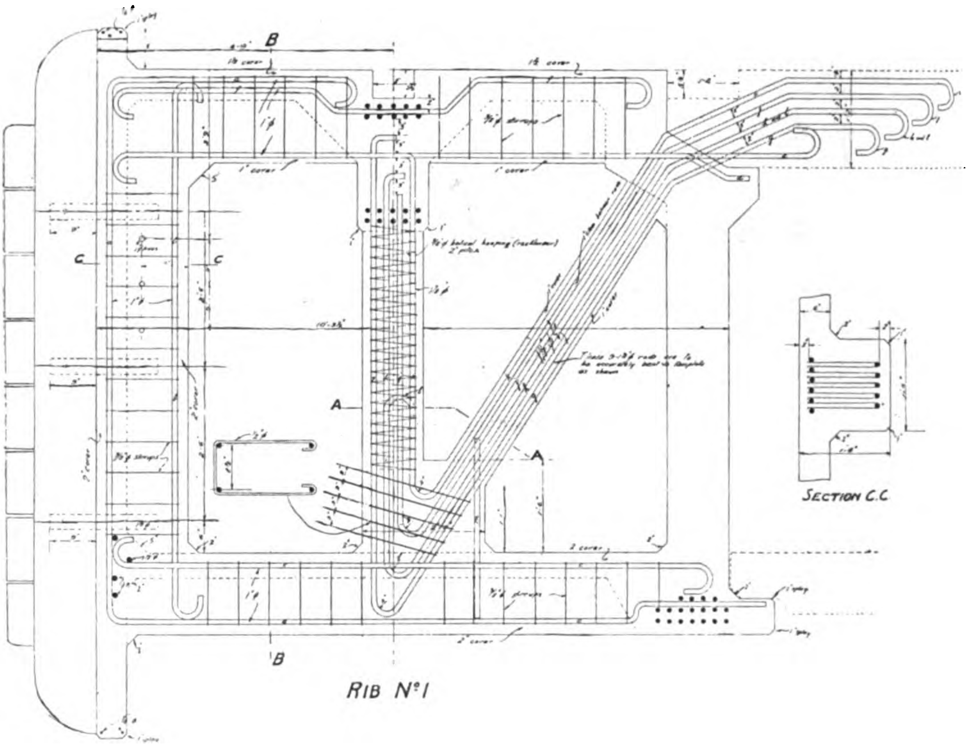


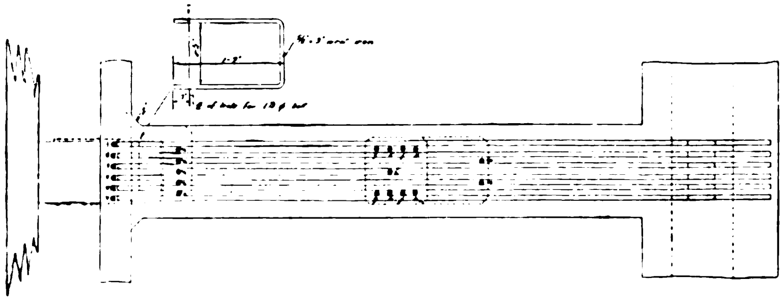
Reinforced Concrete Boxes in Position.



Lowering Reinforced Concrete Box into Position.

REINFORCED CONCRETE QUAY AT TRAFFORD WHARF.


B
A
C
1½ cover
1" cover
2" cover
These 9-1⅛ rods are to be accurately bent to template as shown
RIB No 1
SECTION C.C



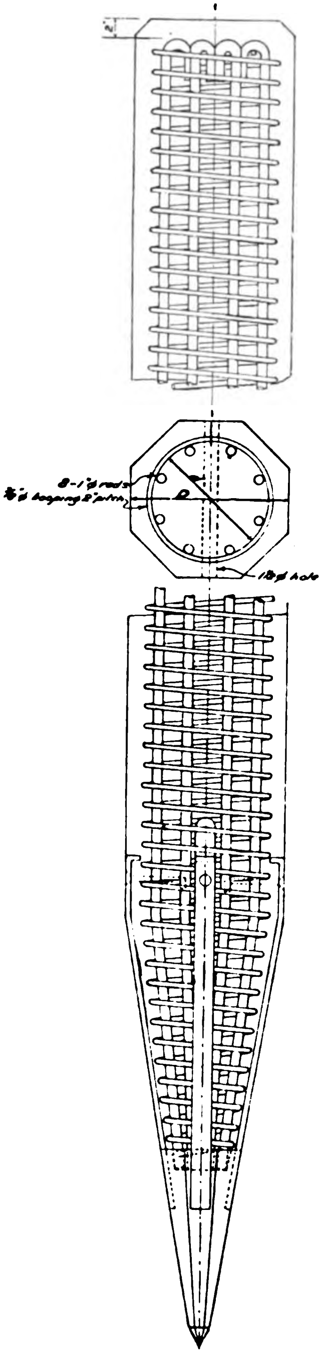
DETAILS OF RIB AND COLUMN OF FRONT CASTING.

transferred to the elevators and silos along the canal. This was made by the insertion of reinforced concrete beams having a span of 15 ft. and a width of 3 ft. 8 in. The device for handling these beams is illustrated herewith ; it has a rectangular steel frame, on which are pivoted two pairs of side arms, and these have chain slings at the ends which are passed over the crane hook. When the load is taken by the crane the top ends of the arms, which cross each other, are drawn in and a pressure is exerted on the beam through the side steel members connecting the lower ends of the lever system. When the reinforced beams had been put into position they were grouted together and the floor covered by a layer of asphalte. The floor level in this subway is just above the water level. The roof of the subway, and also the floor beams connecting the inner pre-cast members to the shed foundations, were formed of a reinforced deck, constructed on steel forms, 100 ft. in length, designed to travel along the length of the wharf as the shuttering was removed after the concrete had set.

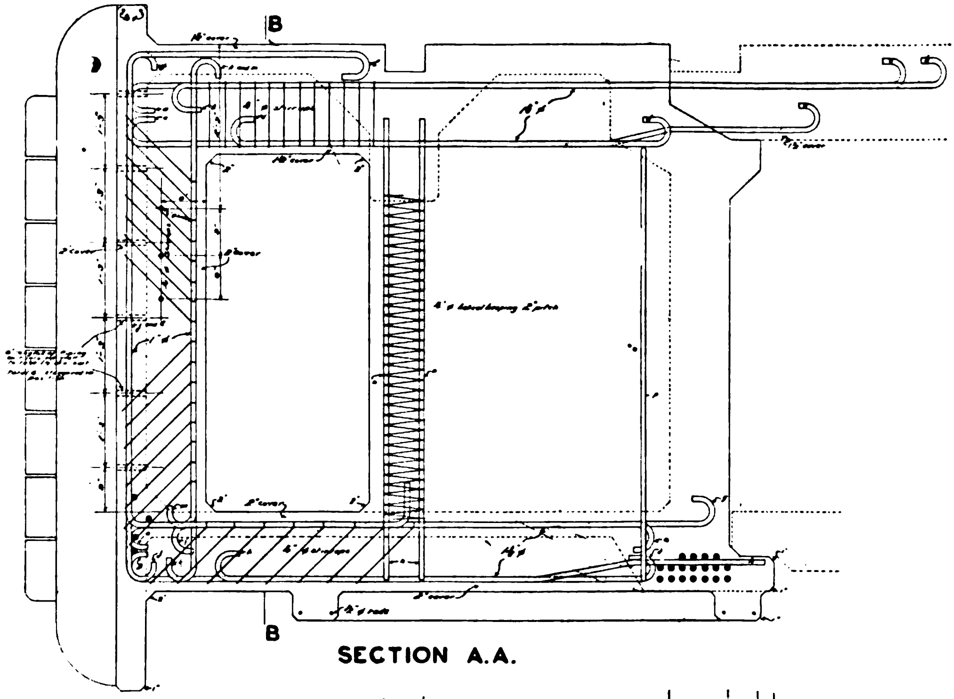
When completed, four transit sheds with five floors will abut upon the wharf, the fronts being actually carried by the wharf. The shed floor beams are carried on the landward side upon the shed foundations.

The floor of the first bay of the sheds consists of the reinforced concrete beams bridging from the inner row of pre-cast boxes and the front row of the foundation blocks. In the spaces between the sheds the beams are continued to form the wharf decking.

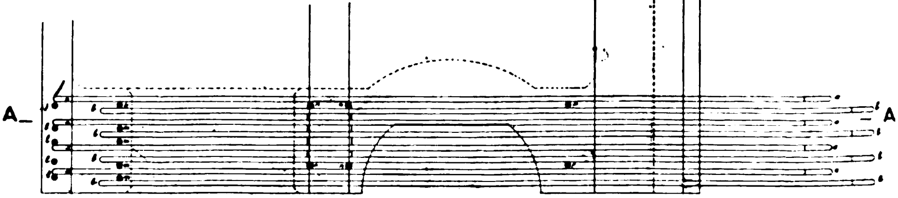
The foundation blocks for the two transit sheds included in this contract are carried upon groups of reinforced concrete piles, with steel spirals and vertical rods, fitted with chilled cast-iron shoes. Octagonal in form, the piles are 15 in. across the flats and from 33 ft. to 40 ft. in length, and have about 21 lbs. of steel per cubic foot of concrete. A floor for the construction of these piles was specially prepared on a site beside the works, which was equipped with a concrete mixer and traveller for distributing the concrete to the pile moulds. An appliance was designed to facilitate handling these long piles, in which they were gripped by wedges in a frame made of rolled steel sections, and could be



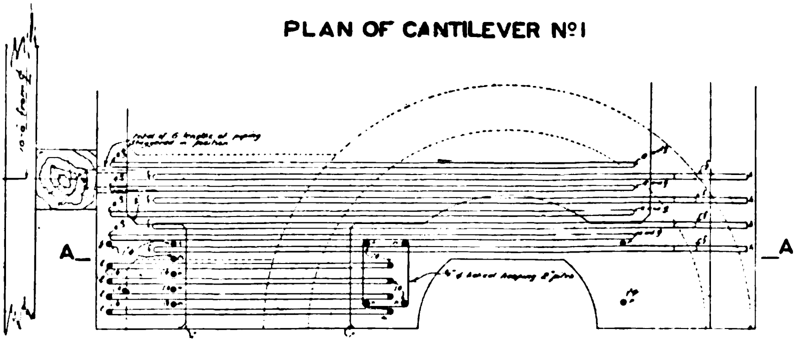
PILE FOR FOUNDATIONS.



SECTION A.A.

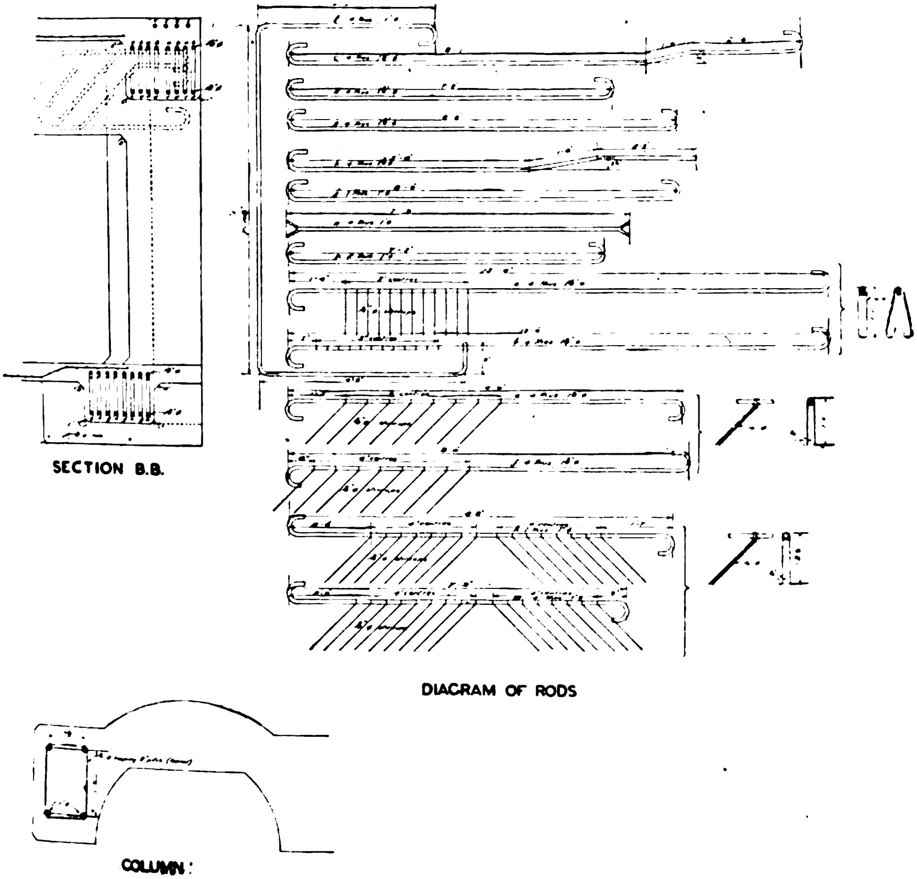


PLAN OF CANTILEVER Nº1



PLAN OF CANTILEVER Nº2

FRONT CASTING, DETAILS OF TOP AND BOTTOM CANTILEVERS NOS. 1 AND 2.



SECTION B.B.

DIAGRAM OF RODS

COLUMN:

FRONT CASTING: DETAILS OF TOP AND BOTTOM CANTILEVERS AND COLUMN No. 2.

lifted without any danger of damage. The piles were then driven into the ground until their tops were about 6 ft. below the surface, and the reinforcements of the heads were bared to connect up with the concrete base. Within the excavation a steel form was erected, and after it was trued up to line and level, it was filled with concrete from the "Insley" tower to form the foundation block for the transit shed columns.

The particulars in this article are based on information supplied by Messrs. Kirk & Randall, Ltd. Details of the front and back walls are given on pp. 268–9.

Standard Specification for Reinforced Concrete.

[*Concluded*].

Reinforced Concrete Columns.

160. The following sections on reinforced concrete columns are based on the assumption of a short column. Where the unsupported length is greater than 40 times the least radius of gyration (40 *R*), the safe load shall be determined by Formula 47. Principal columns in buildings shall have a minimum diameter or thickness of 12 in. Posts that are not continuous from story to story shall have a minimum diameter or thickness of 6 in.

161. The unsupported length of reinforced concrete columns shall be taken as: (*a*) In flat slab construction the clear distance between the floor and under side of the capital; (*b*) In beam-and-slab construction, the clear distance between the floor and the under side of the shallowest beam framing into the column at the next higher floor level; (*c*) In floor construction with beams in one direction only, the clear distance between floor slabs; (*d*) In columns supported laterally by struts or beams only, the clear distance between consecutive pairs (or groups) of struts or beams, provided that to be considered an adequate support, two such struts or beams shall meet the column at approximately the same level and the angle between the two planes formed by the axis of the column and the axis of each strut respectively is not less than 75 deg. nor more than 105 deg. When haunches are used at the junction of beams or struts with columns, the clear distance between supports may be considered as reduced by two-thirds of the depth of the haunch.

162. The safe axial load on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core shall be not greater than that determined by Formula 42. The symbols used in Formulas 42 to 49 are defined in Section 105, except as indicated in Sections 162, 165, 168, 170, 176 and 182.

$$P = A_c f_c + n f_c p A \quad . \quad . \quad (42)$$

where P = total safe axial load on column whose h/R is less than 40;

A = area of the concrete core enclosed within the spiral; the diameter of the core (or of the spiral) shall be taken as the distance centre to centre of the spiral wire;

p = ratio of effective area of longitudinal reinforcement to area of the concrete core;

$A_c = A\ (1 - p)$ = net area of concrete core; and

f_c = permissible compressive stress in concrete =

$$300 + (0{\cdot}10 + 4p)\, f'_c \quad . \quad . \quad (43)$$

The longitudinal reinforcement shall consist of at least six bars of minimum diameter of ½ in., and its effective cross-sectional area shall not be less than 1 per cent. or more than 6 per cent. of that of the core.

163. The spiral reinforcement shall be not less than one-fourth the volume of the longitudinal reinforcement. It shall consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. The spacing of the spirals shall be not greater than one-sixth of the diameter of the core and in no case more than 3 in.

164. Reinforcement shall be protected everywhere by a covering of concrete cast monolithic with the core, which shall have a minimum thickness of 1½ in. in square columns and 2 in. in round or octagonal columns.

165. The safe load on columns reinforced with longitudinal bars and separate lateral ties shall be not greater than that determined by Formula 44.

$$P = (A'_c + A_s n)\, f_c \quad . \quad . \quad (44)$$

The amount of longitudinal reinforcement considered in the calculations shall be not more than 2 per cent. or less than 0·5 per cent. of the total area of the column. The longitudinal reinforcement shall consist of not less than four bars of minimum diameter of ½ in., placed with clear distance from the face of the column not less than 2 in.

166. Lateral ties shall be not less than ¼ in. in diameter, spaced not more than 8 in. apart.

167. Reinforced concrete columns subject to bending stresses shall be treated as follows:

(*a*) *With Spiral Reinforcement.*—The compressive unit stress on the concrete within the core area under combined axial load and bending shall not exceed by more than 20 per cent. the value given for axial load by Formula 43.

(*b*) *With Lateral Ties.*—Additional longitudinal reinforcement may be used if required and the compressive unit stress on the concrete under combined axial load and bending may be increased to 0·30 f'_c. The total amount of reinforcement considered in the computations shall be not more than 4 per cent. of the total area of the column.

Tension in the longitudinal reinforcement due to bending of the column shall not exceed 16,000 lbs. per sq. in.

168. The safe load on composite columns in which a structural steel or cast-iron column is thoroughly encased in a circumferentially reinforced concrete core shall be based on a certain unit stress for the steel or cast-iron core plus a unit stress of 0·25 f'_c on the area within the spiral core.

The unit compressive stress on the steel section shall be not greater than that determined by Formula 45,

$$f_r = 18{,}000 - 70\,h/R \quad . \quad (45)$$

but shall not exceed 16,000 lb. per sq. in.

The unit stress on the cast-iron section shall be not greater than that determined by Formula 46,

$$f_r = 12{,}000 - 60\,h/R \quad . \quad . \quad (46)$$

but shall not exceed 10,000 lbs. per sq. in.

In Formulas 45 and 46,

f_r = compressive unit stress in metal core, and

R = least radius of gyration of the steel or cast-iron section.

The diameter of the cast-iron section shall not exceed one-half of the diameter of the core within the spiral. The spiral reinforcement shall be not less than 0·5 per cent. of the volume of the core within the spiral and shall conform in quality, spacing and other requirements to the provisions for spirals in Section 163.

Ample section of concrete and continuity of reinforcement shall be provided at the junction with beams or girders. The area of the concrete between the spiral and the metal core shall be not less than that required to carry the total floor load of the story above on the basis of a stress in the concrete of 0·35 f'_c, unless special brackets are arranged on the metal core to receive directly the beam or slab load.

169. The safe load on a structural steel column of a section which fully encases an area of concrete, and which is protected by an outside shell of concrete at least 3 in. thick, shall be computed in the same manner as for composite columns in Section 168, allowing 0·25 f'_c on the area of the concrete enclosed by the steel section. The outside shell shall be reinforced by wire mesh, ties or spiral hoops weighing not less than 0·2 lb. per sq. ft. at the surface of the mesh and with a maximum spacing of 6 in. between strands or hoops. Special brackets shall be used to receive the entire floor load at each story. The safe load in steel columns calculated by Formula 45 shall not exceed 16,000 lbs. per sq. in.

170. The permissible working load on the core in axially loaded columns which have a length greater than 40 times the least radius of gyration of the column core (40 R) shall be not greater than that determined by Formula 47,

$$\frac{P'}{P} = 1{\cdot}33 - \frac{h}{120\,R} \quad . \quad . \quad (47)$$

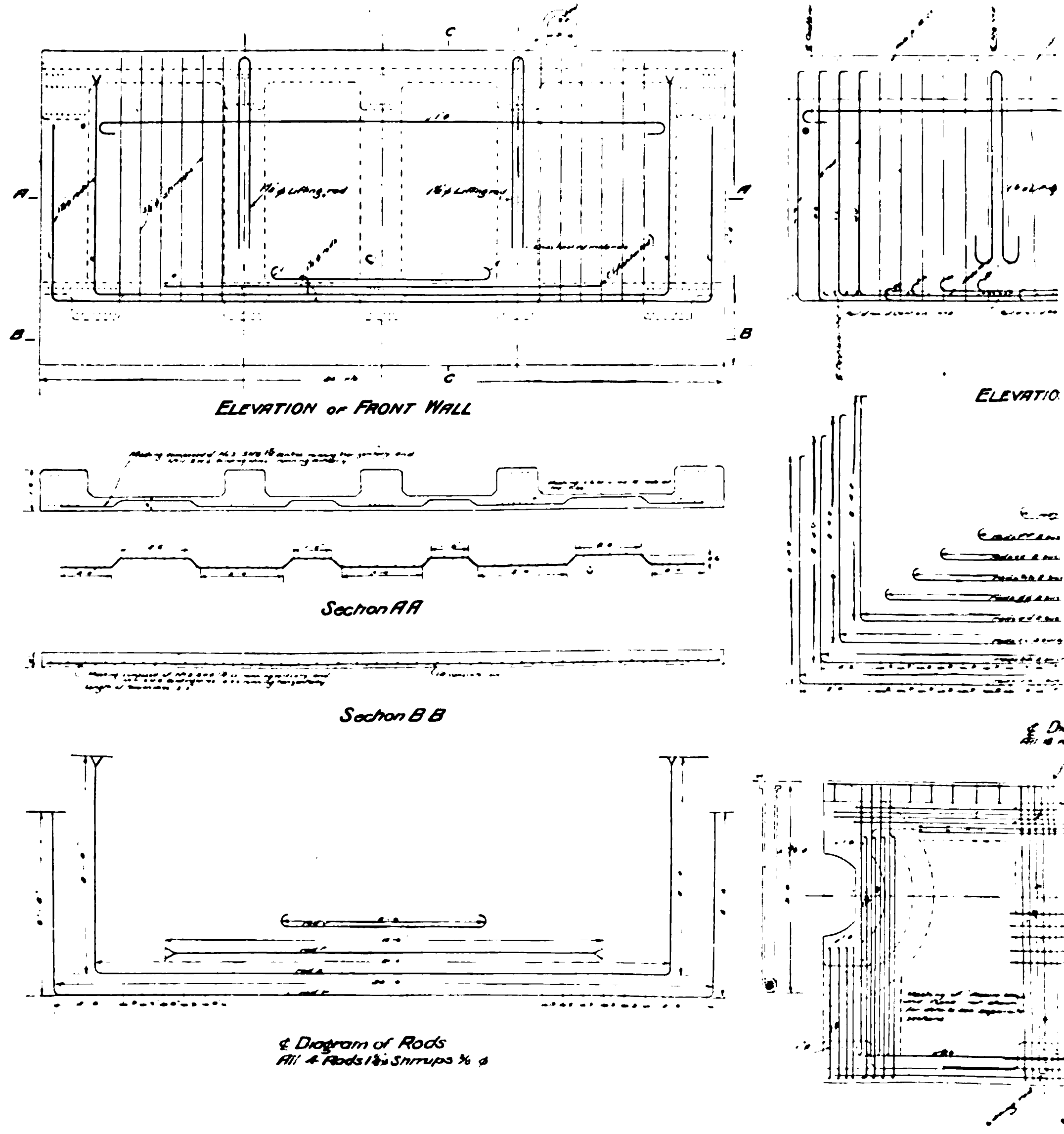
where P' = total safe axial load on long column;

P = total safe axial load on column of the same section whose h/R is less than 40. determined as in Sections 162 and 165; and

R = least radius of gyration of column core.

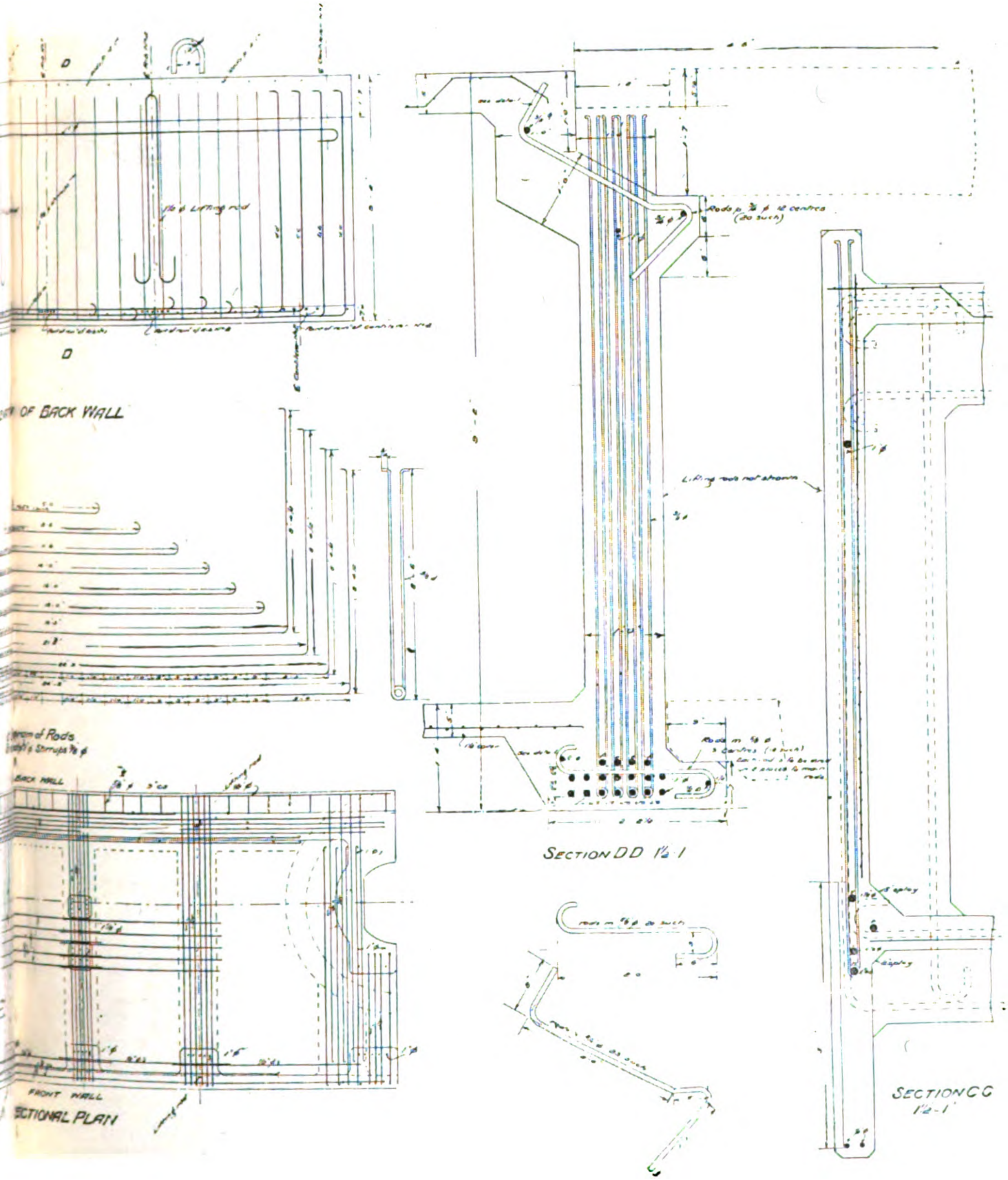
171. The bending moments in interior and exterior columns shall be determined on the basis of loading conditions and end restraint, and shall be provided for in the design. The recognised methods shall be followed in calculating the stresses due to combined axial load and bending. In spiral columns the area to be considered as resisting the stress is the area within the spiral.

(*Continued on p.* 270.)



DETAILS OF FRO

REINFORCED CONCRETE QUAY AT TRAFFORD



AND BACK WALLS

WHARF, MANCHESTER SHIP CANAL. (*See p.* 251.)

Footing.

172. The requirements for tension, compression, shear and bond in Sections 103 and 141, inclusive, shall govern the design of footings, except as hereinafter provided.

173. The load per unit of area on soil footings shall be computed by dividing the column load by the area of base of the footing.

174. Footings on piles shall be treated in the same manner as footings on soil, except that the load shall be considered as concentrated at the pile centres.

175. Footings in which the thickness has been determined by the requirements for shear as specified in Sections 133 and 134 may be sloped or stepped between the critical section and the edge of the footing, provided that the shear on no section outside the critical section exceeds the value specified, and provided further that the thickness of the footing above the reinforcement at the edge shall not be less than 6 in. for footings on soil nor less than 12 in. for footings on piles. Sloped or stepped footings shall be cast as a unit.

176. The critical section for bending in a concrete footing which supports a concrete column or pedestal shall be considered to be at the face of the column or pedestal. Where steel or cast-iron column bases are used the moment in the footing shall be computed at the middle and at the edge of the base; the load shall be considered as uniformly distributed over the column or pedestal base. The bending moment at the critical section in a square footing supporting a concentric square column shall be computed from the load on the trapezoid bounded by one face of the column, the corresponding outside edge of the footing, and the portions of the two diagonals. The load on the two corner triangles of this trapezoid shall be considered as applied at a distance from the face equal to six-tenths of the projection of the footing from the face of the column. The load on the rectangular portion of the trapezoid shall be considered as applied at its centre of gravity. The bending moment is expressed by Formula 48,

$$M = \frac{w}{2}(a + 1{\cdot}2\,c)c^2 \quad . \quad . \quad (48)$$

where M = bending moment at critical section of footing;
a = width of face of column or pedestal;
c = projection of footing from face of column; and
w = upward reaction per unit of area of base of footing.

For a round or octagonal column the distance a shall be taken as equal to the side of a square of an area equal to the area enclosed within the perimeter of the column.

177. The reinforcement in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth shall be the distance from the top of the footing to the plane of the reinforcement. The sectional area of reinforcement shall be distributed uniformly across the footing unless the width is greater than the side of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is spread may be increased to include one-half the remaining width of the footing. In order that no considerable area of the footing shall remain unreinforced, additional reinforcement shall be placed outside of the width specified, but such reinforcement shall not be considered as effective in resisting the calculated bending moment. For the extra reinforcement a spacing double that within the effective belt may be used.

178. The extreme fibre stress in compression in the concrete shall be kept within the limits specified in Section 189. The extreme fibre stress in sloped or stepped footings shall be based on the exact shape of the section for a width not greater than that assumed effective for reinforcement.

179. A rectangular or irregularly shaped footing shall be computed by dividing it into rectangles or trapezoids tributary to the sides of the column, using the distance to the centre of gravity of the area as the moment arm of the upward forces. Outstanding portions of combined footings shall be treated in the same manner. Other portions of combined footings shall be designed as beams or slabs.

182. The compressive stress in longitudinal reinforcement at the base of a column shall be transferred to the pedestal or footing by either dowels or distributing bases. When dowels are used there shall

be at least one for each column bar, and the total sectional area of the dowels shall be not less than the sectional area of the longitudinal reinforcement in the column. The dowels shall extend into the column and into the pedestal or footing not less than 50 diameters of the dowel bars for plain bars, or 40 diameters for deformed bars. When metal distributing bases are used they shall have sufficient area and thickness to transmit safely the load from the longitudinal reinforcement in compression and bending. The permissible compressive unit stress on top of the pedestal or footing directly under the column shall be not greater than that determined by Formula 49,

$$r_a = 0{\cdot}25 f'_c \sqrt[3]{\frac{A}{A'}}. \qquad (49)$$

where r_a = permissible working stress over the loaded area;
A = total area at the top of the pedestal or footing;
A' = loaded area at the column base;
f'_c = ultimate compressive strength of concrete. (See Section 120.)

In sloped or stepped footings A may be taken as the area of the top horizontal surface of the footing or as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base the loaded area A', and having side slopes of 1 vertical to 2 horizontal.

183. The allowable compressive unit stress on the gross area of a concentrically loaded pedestal or on the minimum area of a pedestal footing shall not exceed 0·25 f'_c, unless reinforcement is provided and the member designed as a reinforced concrete column. The depth of a pedestal or pedestal footing shall be not greater than three times its least width, and the projection on any side from the face of the supported member shall be not greater than one-half the depth. The depth of a pedestal whose sides are sloped or stepped shall not exceed three times the least width or diameter of the section midway between the top and bottom. A pedestal footing supported directly on piles shall have a mat of reinforcing bars having a cross-sectional area of not less than 0·20 sq. in. per foot in each direction, placed 3 in. above the top of the piles.

Reinforced Concrete Retaining Walls.

184. Reinforced concrete retaining walls shall be so designed that the permissible unit stresses specified in Sections 186 to 197 are not exceeded. The heels of cantilever, counterforted, and buttressed retaining walls shall be proportioned for maximum resultant vertical loads, but when the foundation reaction is neglected the permissible unit stresses shall not be more than 50 per cent. greater than the normal permissible stresses.

185. The following principles shall be followed in the design of reinforced concrete retaining walls:

(*a*) The unsupported toe and heel of the base slabs shall be considered as cantilever beams fixed at the edge of the support.

(*b*) The vertical section of a cantilever wall shall be considered as a cantilever beam fixed at the top of the base.

(*c*) The vertical sections of counterforted and buttressed walls and parts of base slabs supported by the counterforts or buttresses shall be designed in accordance with the requirements for a continuous slab in Section 110.

(*d*) The exposed faces of walls without buttresses shall preferably be given a batter of not less than ¼ in. per ft.

(*e*) Counterforts shall be designed in accordance with the requirements for T-beams in Sections 113 to 115. Stirrups shall be provided in the counterforts to take the reaction when the tension reinforcement of the face walls and heels of bases is designed to span between the counterforts. Stirrups shall be anchored as near the exposed face of the longitudinal wall and as close to the lower face of the base as the requirements for protective covering permit.

(*f*) Buttresses shall be designed in accordance with the requirements specified for rectangular beams.

(*g*) The shearing stress at the junction of the base with counterforts or buttresses shall not exceed the values specified in Sections 120 to 130.

(*h*) Horizontal metal reinforcement shall be of such form and so distributed as to develop the required bond. To prevent temperature and shrinkage cracks in exposed surface not less than 0·25 sq. in. of horizontal metal reinforcement per foot of height shall be provided.

(*i*) Grooved lock joints shall be placed not over 60 ft. apart to care for temperature changes.

(*j*) Counterforts and buttresses shall be located under all points of concentrated loading, and at intermediate points, as may be required by the design.

(*k*) The walls shall be cast as a unit between expansion joints, unless construction joints formed in accordance with Sections 69 and 73 are provided.

(*l*) Drains or weep holes not less than 4 in. in diameter and not more than 10 ft. apart, shall be provided. At least one drain shall be provided for each pocket formed by counterforts.

Summary of Working Stresses.

186. The following working stresses shall be used:

where f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with standard methods.

Direct Stress in Concrete.

187. (*a*) Columns whose length does not exceed $40R$:
    (1) With spirals . . . . . varies with amount of longitudinal reinforcement (See Section 162.)
    (2) Longitudinal reinforcement and lateral ties. (See Section 165.)
  (*b*) Long columns. (See Section 170.)
  (*c*) Piers and Pedestals . . $0{\cdot}25f'_c$ (See Section 183.)

188. (*a*) Extreme fibre stress in flexure . . . $0{\cdot}40f'_c$
  (*b*) Extreme fibre stress in flexure adjacent to supports of continuous beams . . $0{\cdot}45f'_c$

189. In concrete members . . None

Shearing Stresses in Concrete.

190. (*a*) Beams without web reinforcement . . . $0{\cdot}02f'_c$
  (*b*) Beams with stirrups or bent-up bars or combination of the two . . . . $0{\cdot}06f'_c$

191. (*a*) Beams without web reinforcement . . . $0{\cdot}03f'_c$
  (*b*) Beams with stirrups or bent-up bars or a combination of the two . . . . $0{\cdot}12f'_c$

192. (*a*) Shear at distance *d* from capital or dropped panel . . . . $0{\cdot}03f'_c$
  (*b*) Other limiting cases in flat slabs. (See Section 131.)

193. (*a*) Longitudinal bars without special anchorage . . . . $0{\cdot}02f'_c$
  (*b*) Longitudinal bars having special anchorage. $0{\cdot}03f'_c$

Stresses in Reinforcement.

194. (*a*) Billet-steel bars: lbs. per sq. in.
    (1) Structural steel grade 16,000
    (2) Intermediate grade. 18,000
    (3) Hard Grade . . . 18,000
  (*b*) Rail-steel bars . . . 18,000
  (*c*) Structural steel . . . 16,000
  (*d*) Cold-drawn steel wire:
    (1) Spirals. Stress not calculated.
    (2) Elsewhere . . . 18,000

195. (*a*) Bars. Same as Section 194 (*a*) and (*b*)
  (*b*) Structural steel core of composite column 16,000 Reduced for slenderness ratio. (See Section 168.)
  (*c*) Structural steel column. 16,000 Reduced for slenderness ration. (See Section 169.)

196. Composite cast-iron column 10,000 Reduced for slenderness ratio. (See Section 168) . .

197. (*a*) Beams and slabs, plain bars . . . . $0{\cdot}04f'_c$
  (*b*) Beams and slabs, deformed bars . . $0{\cdot}05f'_c$
  (*c*) Footings, plain bars, oneway . . . . $0{\cdot}04f'_c$
  (*d*) Footings, deformed bars, one-way . . . $0{\cdot}05f'_c$
  (*e*) Footing, bars two ways (*c*) or (*d*) reduced by 25 per cent.

Local Authorities and All-Concrete Roads.

A TEST CASE.

A TEST case affecting the right of local authorities to set up a definite standard for private street works was decided in the Kingston Petty Sessional Court on February 16.

The London Property Owners' Protection Association, on behalf of 64 owner-occupiers of new houses on the Ballard Estate, New Malden, petitioned against the proposal of the Malden and Coombe Urban District Council to make-up new streets in reinforced concrete on the grounds that such roads were roads for posterity, and beyond the reasonable traffic requirements of the district.

Dr. R. C. Maxwell appeared for the Council, and Mr. E. J. Naldrett for the London Property Owners' Protection Association and the owners.

Dr. Maxwell, in opening the case, said the New Malden Council had seriously considered the question of making-up private streets, and under the advice of an eminent engineer, in consultation with their own engineer, had adopted a general policy. Several cases had already been before the Bench and the Council had uniformly obtained a decision in favour of their specification. The Council held that they ought not to sacrifice the interests of the public to the interests of the owners. The cost of constructing the proposed three roads in reinforced concrete was 33*s.* 11½*d.*, 34*s.* 3*d.*, and 34*s.* 0½*d.* per foot frontage respectively, or 6*d.* a foot less than in the last case brought before the Court where the works were tar macadam and gravel. Speaking of the Council's decision to adopt concrete roads, Dr. Maxwell said—" This is an age of concrete, and everything is changing. The whole aspect of street works has changed in the past few years, putting nearly everything out-of-date. We have merely moved with the times, recognising this new factor."

Mr. Reginald Jeffes, Surveyor to the District Council, said that the specifications included a 24-ft. carriage-way of 6 in. reinforced concrete with 3 in. of clinker underneath, two 8 ft. footpaths of 2 in. artificial stone slabs on a 4 in. foundation of hard-core, and a granite kerb-stone. No channelling was required for a concrete road, which was a considerable saving on old methods. He regarded flint as quite obsolete having regard to the class of traffic roads had to carry nowadays.

Cross-examined by Mr. Naldrett, Mr. Jeffes agreed that the roads would carry mainly local traffic, but not through traffic. The made-up portions in water-bound macadam were built before the war.

The Chairman (Mr. W. Negus) : Why not carry the road through in the old materials ?—Because I consider concrete a superior material. Mr. Jeffes added that all Surveyors who had done work of a similar character agreed with his figures showing that concrete was the cheapest method. He admitted that reinforced concrete was possibly a new departure for private street works, but there had to be a beginning with everything. Even in side streets serving cottage properties reinforced concrete roads were reasonable.

Mr. Naldrett : You have adopted a general policy of reinforced concrete ?—Yes.

Regardless of what or where the street is ?—No, not where work of a substantial character has already been done. Where roads are to be made *de novo* the standard requirement is reinforced concrete.

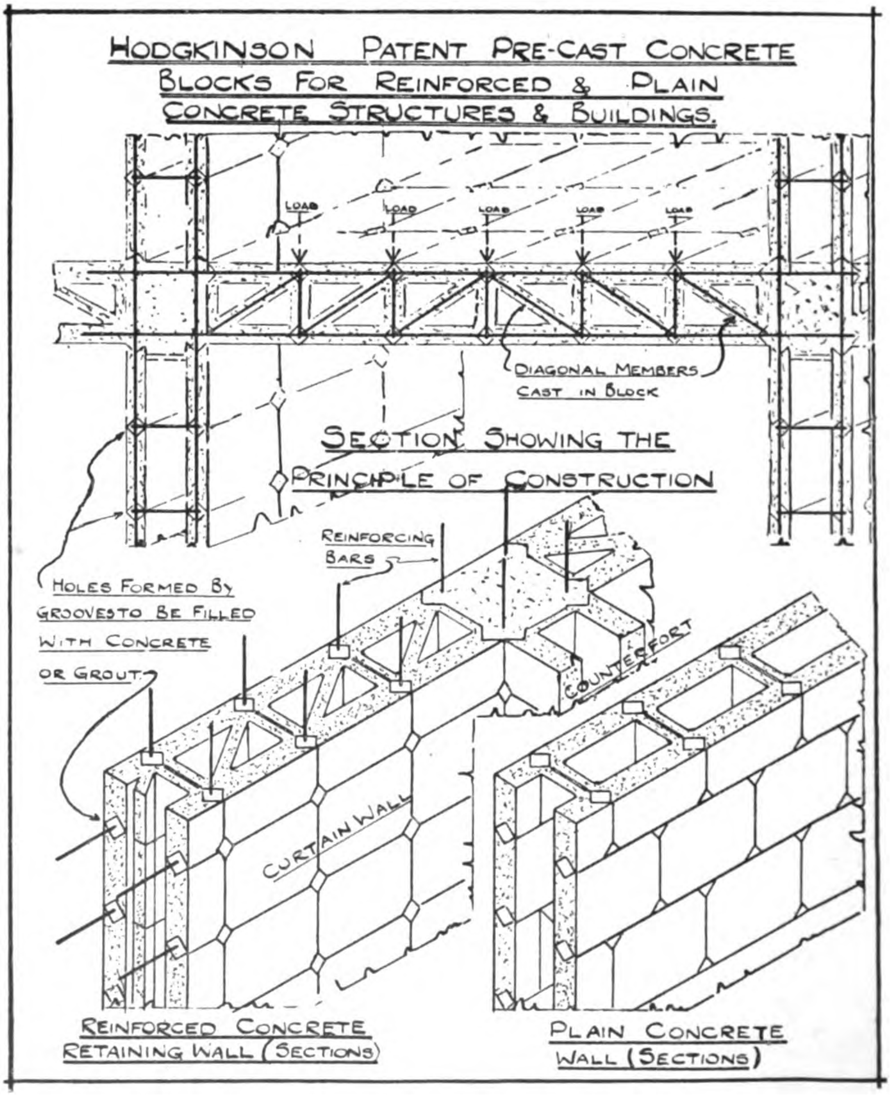
Mr. Jeffes expressed the opinion that Surveyors were only just becoming alive to the advantage of concrete.

Mr. E. J. Elford, M.Inst.C.E. (Past President of the Institution of Municipal and County Engineers, and Engineer and Surveyor of Wandsworth), said concrete was the cheapest form of construction of a satisfactory nature for all roads in the same condition as those on the Ballard Estate. Last year he put out to tender eight roads for tar-mac and concrete alternatively. In the aggregate, concrete was 10 per cent., or £1,700, cheaper. " We have found concrete the cheapest form of construction and the most satisfactory," he added. He was a party to and largely responsible for the drawing-up of the Ministry of Health suggested specification ; nevertheless, he thought concrete most suitable for residential streets even in an urban district like Malden.

For the property owners, Mr. A. C. Parnacott, said reinforced concrete for private streets was a new feature, and he did not think it was a fair charge upon owners. He suggested as an alternative a 10-ft. roadway, 4-ft. tar-pavement with gravel edge, and concrete kerb to the roadway. This would save 10*s*. 7*d*. per foot. The carriage-way would be 9 in. consolidated hard-core and 3 to 4 in. of tar-mac.

Counsel: Concrete saves the rate-payers' money in the future?—It is a saving for posterity.

Mr. Naldrett, on behalf of the owners, said the question was whether the local authority was justified in requiring its new standard to be carried out at the cost of the frontagers. The owners had


Hodgkinson Patent Pre-Cast Concrete Blocks for Reinforced & Plain Concrete Structures & Buildings.
Load
Load
Load
Load
Load
Diagonal Members Cast in Block
Section Showing the Principle of Construction
Reinforcing Bars
Holes Formed By Grooves to Be Filled With Concrete or Grout
Counterfort
Curtain Wall
Reinforced Concrete Retaining Wall (Sections)
Plain Concrete Wall (Sections)

(*See p.* 275.)

good reason to object, because the local authority was making requirements far in excess of the needs of those streets. In adopting a standard specification applicable to all streets, the local authority was wrong, because if there were one principle associated with the administration of the Act it was that they must make-up a street as they found it and in accordance with the present needs of the locality. It was not intended that the owners should provide streets for all time. The proposed concrete roads would saddle the owners with the expense of roads designed for posterity. The law did not allow that. A local authority could not determine a general specification for every street.

After a long retirement the Magistrates announced their decision that the specifications should be amended to provide for roads of a similar character to the existing portions of the roads, namely, water-bound macadam. The pavements should be from 4 to 5 ft. in width with gravel or other verge.

New Type of Pre-Cast Concrete Block.

We have received from Mr. A. J. Hodgkinson, of Middleton, Leeds, some particulars and the accompanying drawing (see p. 274) relating to a patent pre-cast concrete block for reinforced or plain concrete structures. The claims made for this type of block are as follows:—

(1) A reinforced concrete structure or building can be erected without the use of shuttering and skilled labour.

(2) The blocks can be made with an aggregate such as ashes or slag, which, if it came into direct contact with the reinforcing bars would be highly injurious to them; the reinforcing bars have a protecting cover of concrete or grout between the bar and the pre-cast block.

(3) Increased moment of resistance and radius of gyration of the section are obtained by eliminating that concrete nearest to the neutral axis of the section which is wasted by being under-stressed, the shear stresses being taken by the diagonal member cast in the block.

(4) The blocks can be made from a mixture of concrete the strength of which is relative to the position of the blocks in the structure.

(5) A reduction is made in the time of construction.

(6) When the blocks are used on work below ground level which must be loaded with a displacement load, the hollow portion of the block can be filled with the excavated material; also a reduction is made in the amount of excavation for the structure.

(7) The spacing of the bars is fixed by the size of the block, and the position of the reinforcing bars in the structure is known.

(8) When rapid-hardening cement is used on the structure a reduction is made in the amount used.

(9) The building is provided with a ventilated cavity around the structure in which cables, water and gas mains, drains, etc., can be fixed.

(10) The faces of the blocks can be coloured or made with an aggregate to suit the different conditions existing on the inner and outer surfaces of the building.

(11) When the blocks are used in a plain concrete structure they are bonded one with another; the reinforcing bars can be omitted and the grooves filled with concrete or grout.

(12) The concrete or grout around the bars and filling the holes formed by the grooves is under pressure due to the head in the vertical holes; this pressure is approximately 1 lb. per sq. in. per foot head.

Back Numbers Wanted.—A Correspondent is desirous of obtaining copies of "Concrete and Constructional Engineering" for August, 1919; May, August and October, 1920; January and July, 1921; and January and February, 1922. Replies should be sent to Box 1284, Concrete and Constructional Engineering, 20 Dartmouth Street, Westminster, London, S.W.1.

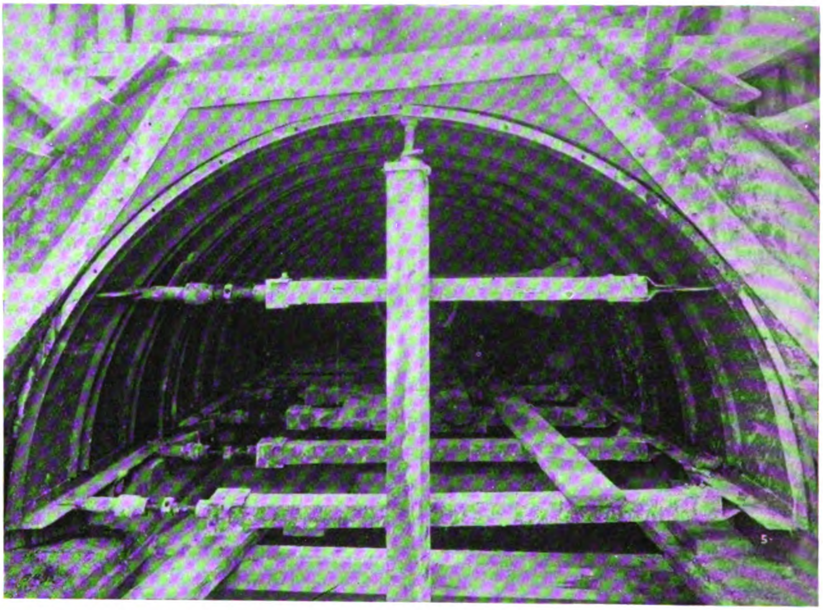


FIG. 133.—HALF-ROUND SEWER FORMS WITH TIMBER TIES AND SCREW JACKS FOR COLLAPSING.

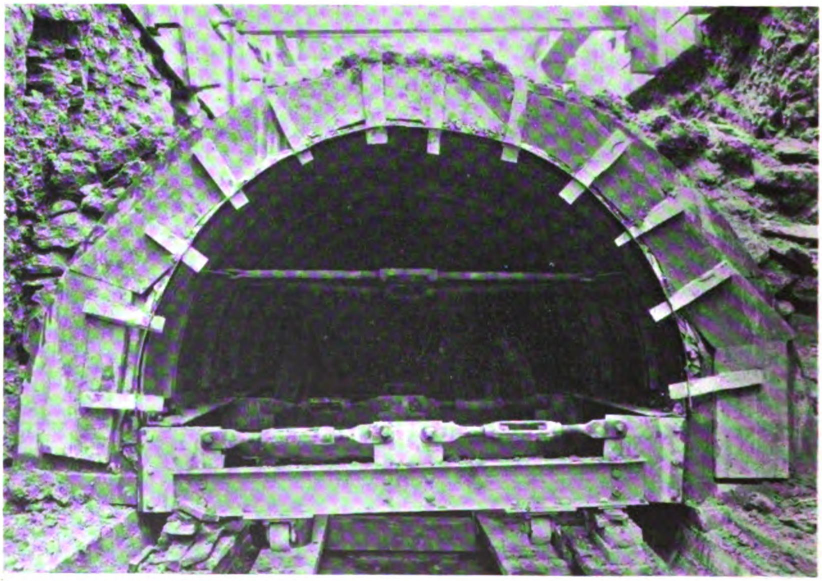


FIG. 134.—A 78-IN. HALF-ROUND SEWER FORM WITH TRAVELLER ATTACHED.

(*See p.* 277.)

Design of Formwork for Reinforced Concrete Construction.

By A. E. Wynn, B.Sc., A.M.Am.Soc.C.E.

XVII.—STEEL FORMS FOR CURVED SURFACES.

Conduits and sewers, grain bins and silos, penstocks, subways and tunnels are structures in the construction of which steel forms have almost entirely superseded wood, and engineers' specifications now often insist that steel forms be used for these structures.

These forms are always fairly difficult to make in wood; they can only be used a limited number of times; owing to hard handling they have to be repaired frequently, they do not keep their shape so well as steel, and do not give so smooth a finish. Also, wood forms are more difficult to strip and move, as they require rigid joints and bracing.

Structures through which sewage or water flows are required to be smooth to lessen the friction, so that steel forms are particularly suitable for sewers and conduits and result in a large saving in the cost of finishing the concrete. Usually the contracts for these structures are so large that even if the forms have to be specially made they will pay for themselves on one job.

Steel forms will retain their shape; at the same time, owing to their flexibility, they can be easily and quickly collapsed for moving ahead. Another advantage is the absence of bracing, allowing more working space within the form.

In general the forms are built of steel plates and angle-iron stiffeners.

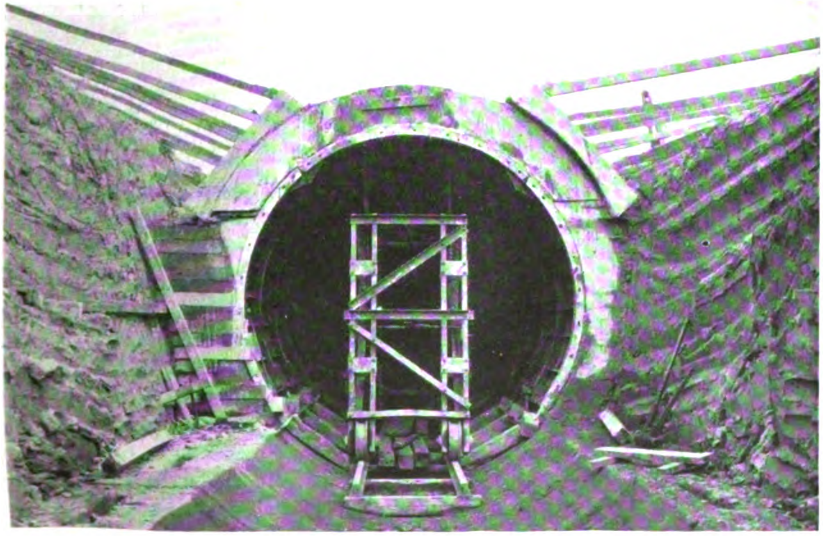


Fig. 135.—Circular Sewer Form, 11 ft. 6 in. Diameter, with Traveller running on Tracks.

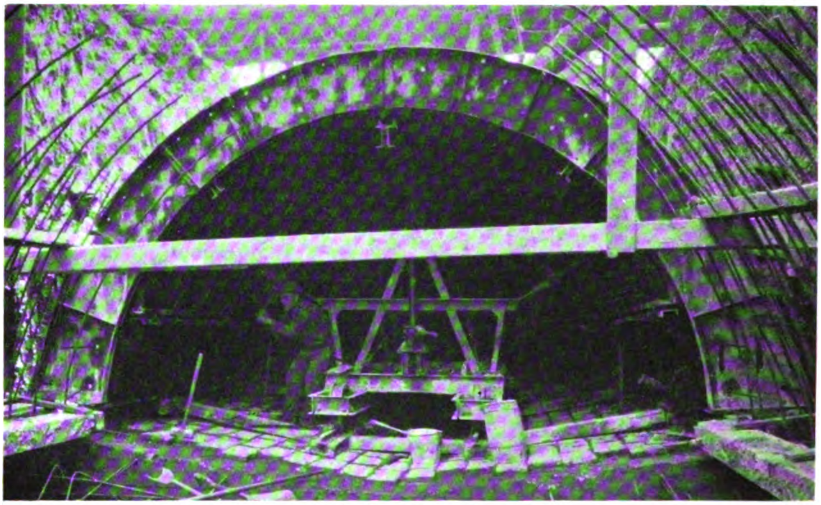


FIG. 136.—A 15-FT. DIAMETER SEGMENTAL SEWER FORM WITH TRAVELLER.

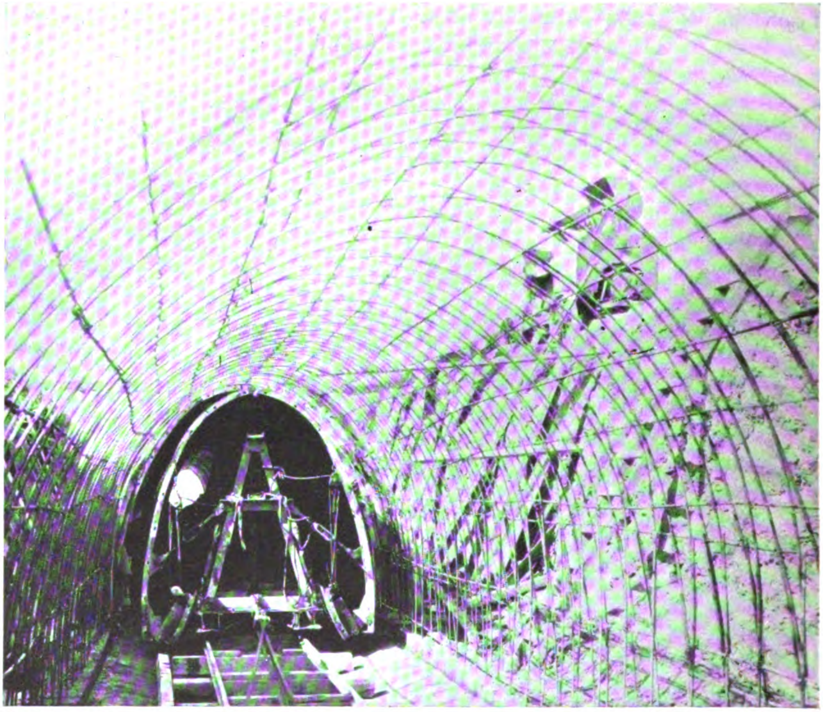


FIG. 137.—HORSE-SHOE SEWER FORM, SHOWN COLLAPSED AND BEING PULLED THROUGH ERECTED FORM.

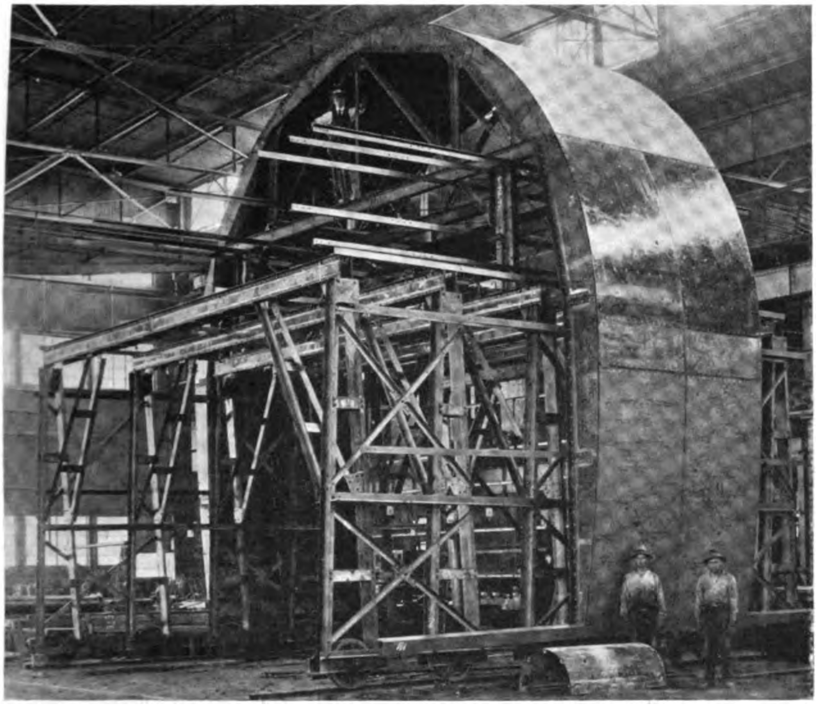


FIG. 138.—TRAVELLING TUNNEL FORM, 32 FT. DIAMETER BY 32 FT. HIGH.

Their construction and use are clearly shown in the photographs.

Sewers.—To eliminate friction in the finished sewer the forms are made up with as few joints as possible in the plates. Forms for 15-ft. diameter structures can be built with longitudinal joints only at the crown and springing lines and cross joints 5 ft. apart. There are endless diameters and shapes for sewers; some of the most typical are illustrated.

The simplest form is the circular sewer. To form these a half-round form is generally used, laying the invert first and the crown afterwards. They are made up in 5-ft. sections interlocking together, using as many sections as are required by the speed of the job and facilities for handling the concrete. They are collapsed usually by turnbuckles, which can be seen in the pictures. Another method of collapsing is by means of screw jacks fastened to one end of timber ties (*Fig.* 133). When used for the invert the forms are suspended from an overhead I-beam track by trolley hangers running on the lower flange of the beam. When used for the crown the smaller sizes have two rollers—short pieces of pipe—on the turnbuckles which run on a plank track when moving, the entire unit moving at one operation.

The larger sizes are equipped with travellers, consisting of channels with rollers attached, running on plank runways laid on the invert (*Fig.* 134). The traveller and form may form one unit or the traveller may be independent, handling several sections which when collapsed move through the forms ahead.

An almost complete circular form for an 11-ft. 6-in. diameter sewer is shown in *Fig.* 135. This is moved by a traveller running on tracks laid on the invert.

Fig. 136 shows the forms for a 15-ft. diameter segmental sewer with the traveller attached. (Note the man operating the turnbuckles by which the form is collapsed also the steel bulkhead.)

Forms for a horse-shoe shape sewer are shown in *Fig.* 137. This form is in the collapsed condition and is being pulled forward on a track by the attached ropes and block, telescoping through the erected form. It will be seen that very little time is required to set the form, and that concreting may be an almost continuous operation. Contrast the labour required in this method with that required in taking apart the sections of a wood form and re-erecting them.

Tunnels and Subways.—These are some of the largest structures in which steel forms are used. They are particularly suitable and economical for such structures, as they are easy to strip and move ahead, and give a large clear working space, which is important when cars are carrying out the excavated material through the forms.

Fig. 138 shows a typical steel form with traveller for a tunnel 32 ft.

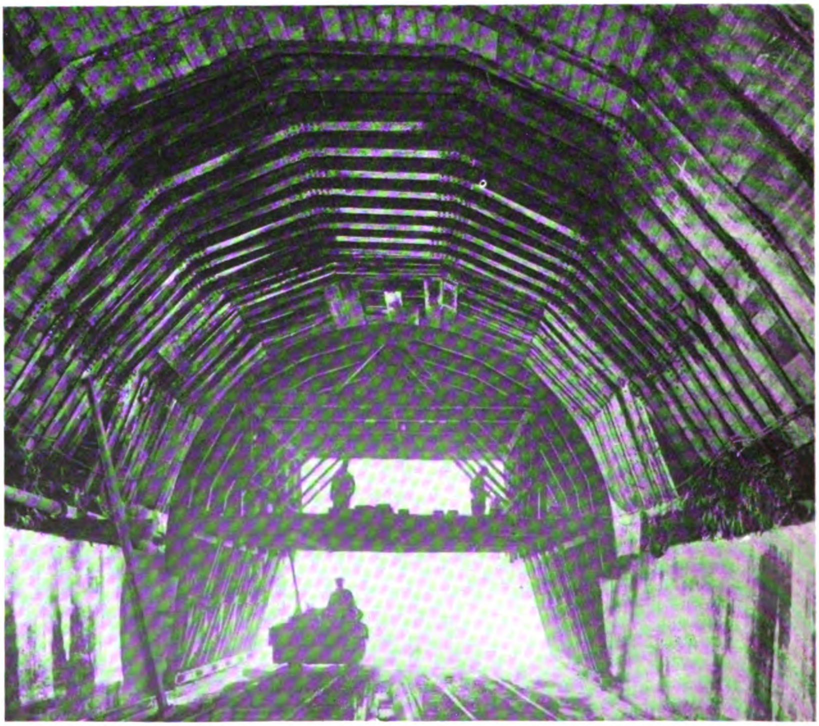


Fig. 139.—Trussed Tunnel Form in Position for Concreting.

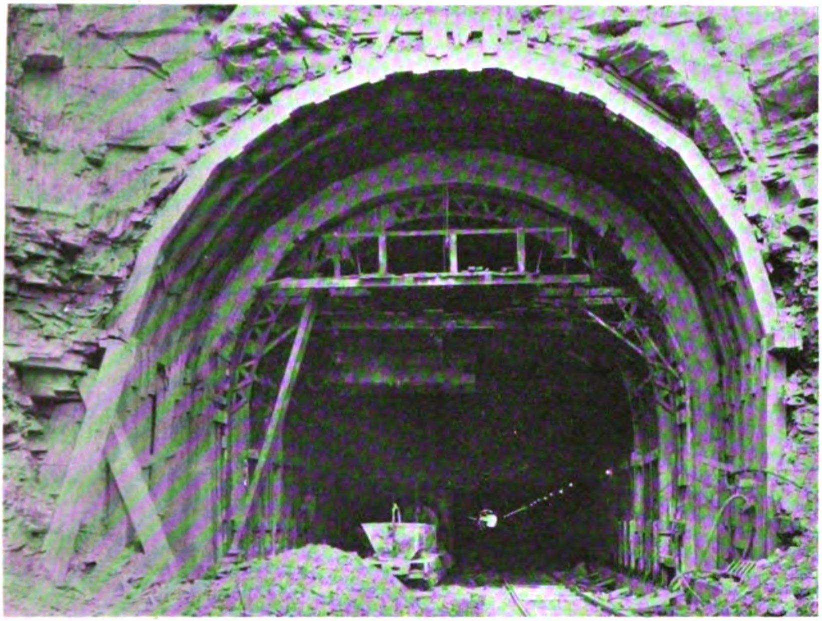


FIG. 140.—ARCH RIB TUNNEL FORM, GIVING LARGE WORKING SPACE.

diameter by 32 ft. high. The large size of the plates with few joints, giving perfectly smooth surfaces, should be noted. This form was used by the Niagara Falls Power Co.

Fig. 139 shows a tunnel form used in the construction of the Liberty Tunnel at Pittsburgh, U.S.A. The form is in place ready for concreting. The whole width of the tunnel is available as working space. The lagging seen at the top of the tunnel is to hold back the earth and rock and is concreted in. This form is of truss design.

Fig. 140 shows a travelling tunnel form of arch rib design, giving a still greater working space.

Fig. 141 illustrates the use of steel forms in building a twin subway.

Penstocks.—These are similar in design to sewers and conduits, but are often much larger in diameter. *Fig.* 142 shows a travelling penstock form 21 ft. in diameter, used by the Niagara Falls Power Co. It is shown at the mouth of a tunnel. All the forms shown in *Figs.* 133 to 142 were designed and manufactured by the Blaw-Knox Co., by whose courtesy they are reproduced.

Silos and Grain Bins.—All the forms described above travel horizontally. We will now consider forms which move vertically. Tanks are not mentioned because they are usually built with wood sliding forms to avoid construction joints, but they can be built with steel forms in the same manner as silos.

The forms for these structures do not move as a whole, nor are they continuously sliding forms. Instead, the method used is to build the forms of a number of square curved plates interlocking, similar to light

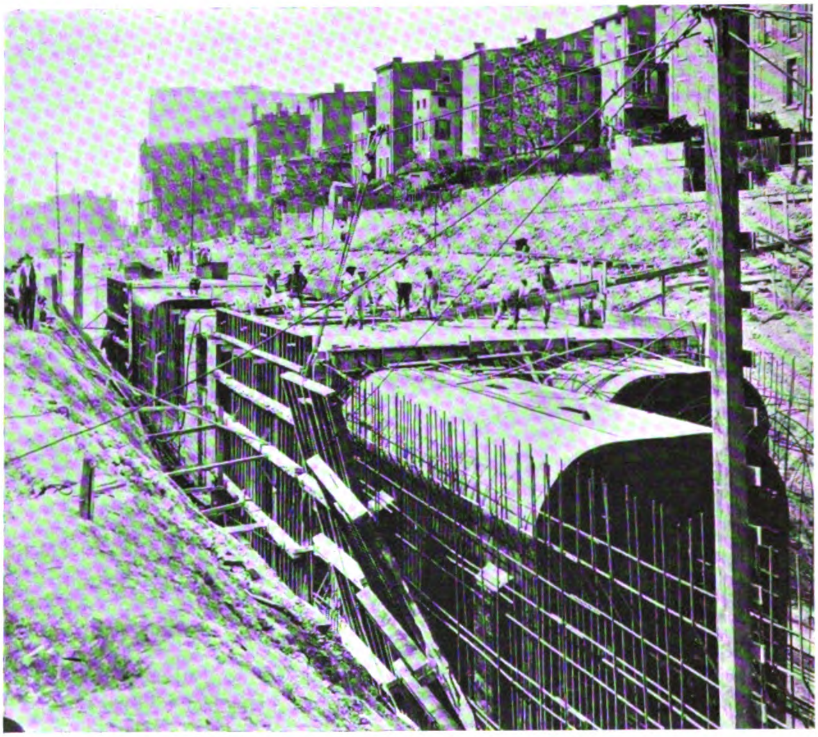


FIG. 141.—TWIN SUBWAY FORMS.

wall forms. For large-diameter structures the curvature in the 2-ft. width of a plate will be small, so ordinary straight wall forms may be used in the same manner as for walls. Two or three courses are used, moving one above the other (*Fig.* 143).

For smaller diameters, particularly for silos and grain bins, the plates are attached to radial angle-iron arms at the top and bottom. The radial arms end in collars which slide over a vertical pipe, resting on a casting at the bottom. There are holes at intervals of 24 in. through the pipe, through which short rods can be slipped to help support the collars, which are in two parts bolted together against the pipe.

The "Metaform" method of assembly of the plates and arms is clearly shown in *Fig.* 144. Each unit is self-contained, there being no loose parts. It will be seen that the plates are connected sideways by two clamps which are connected to the plates and vertically by a clamp engaging in an eye in the plate above. The arms rest on two circumferential rings. The forms are adjustable to different diameters by inserting similar plates of different widths, and the arms telescope to suit different diameters. Spacers slipped over the tops of the plates hold the inner and outer form the correct distance apart. Scaffold planks are thrown over the upper arms to form a working platform.

For ordinary silos or bins two courses are used, pouring 4 ft. the first day and 2 ft. each succeeding day, stripping in the morning and pouring in the afternoon. If there is a battery of bins, better time can be made with three courses pouring 4 ft. a day. The outside panels are removed first and set in place on top of the upper course; then the reinforcing steel is placed; and, lastly, the inside form. The outside panels are handled one by one from the top with a long hook which loosens the clamps, engages the eyes of the top clamps, and lifts the panels up to the course above. The inside panels and the arms are unclamped and raised by hand.

Fig. 145 shows two three-course outfits in use, and *Figs.* 146 and 147 various stages in the construction of a battery of four grain bins, the bins being carried up together. As pouring thin walls at a great height is always troublesome, the Metal Forms Corporation provide with their silo forms a hoisting attachment, which is a light steel derrick supported by the pipe mast and the forms, and a distributor which is a tip bucket running on a circular track near the inside form. Hoist and distributor can be seen at the top of the bins in *Fig.* 145. A similar bucket is used for hoisting the concrete, so that one bucket is being emptied while the other is being filled.

For combinations of bins special connecting pieces are made, *Fig.* 147. Steel door, chute, and roof forms are made for use in silo construction.

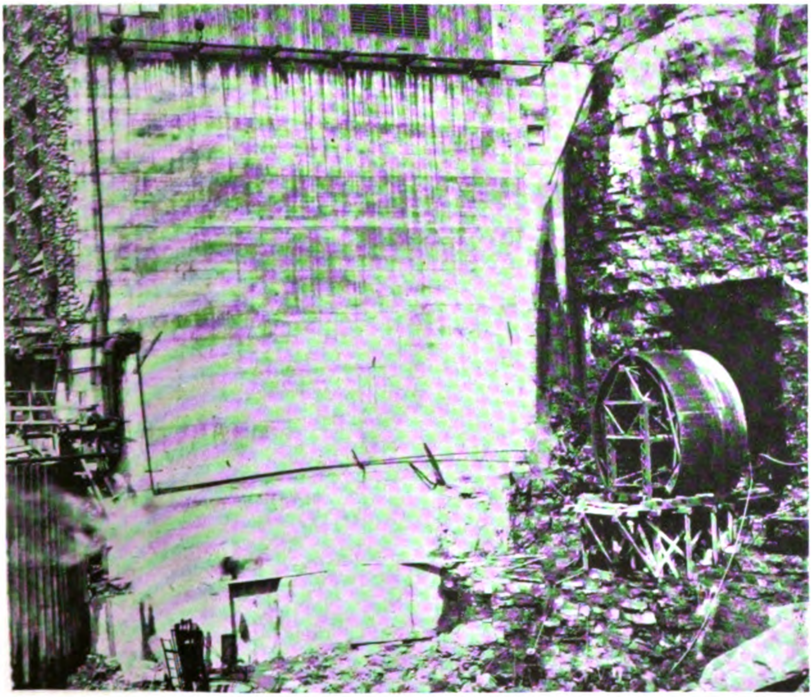


Fig. 142.—A 21-ft. Diameter Penstock Form.

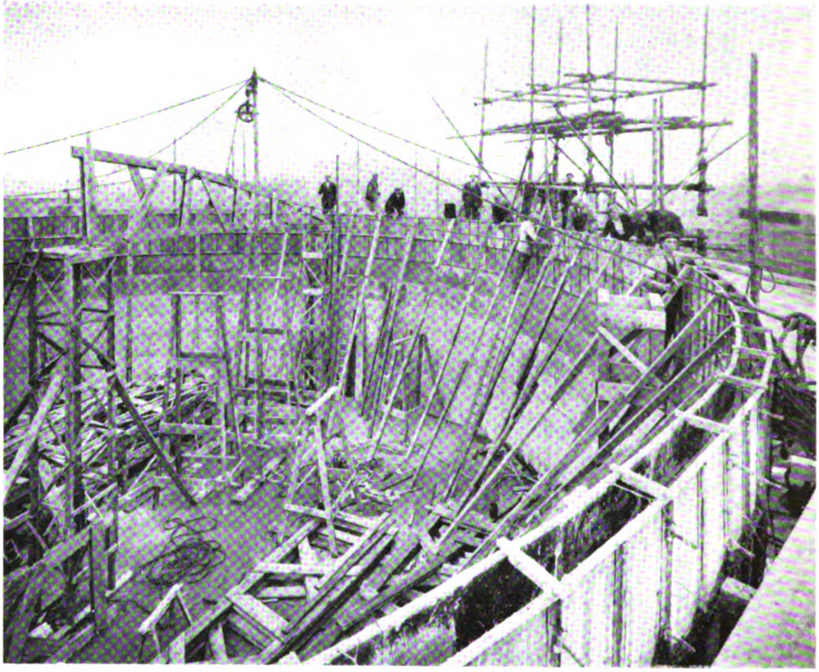


Fig. 143.—Metal Forms for Circular Structures.

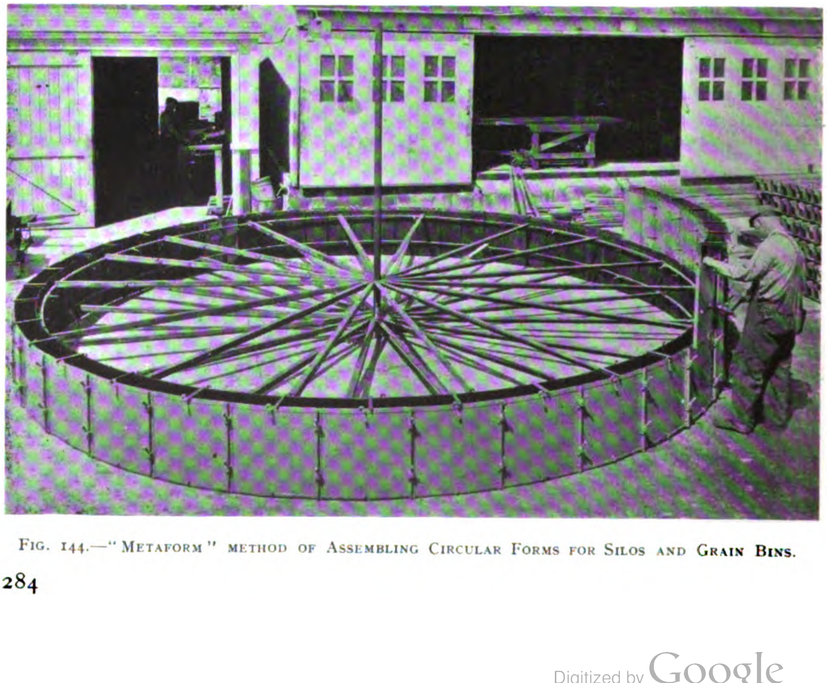


Fig. 144.—"Metaform" method of Assembling Circular Forms for Silos and Grain Bins.

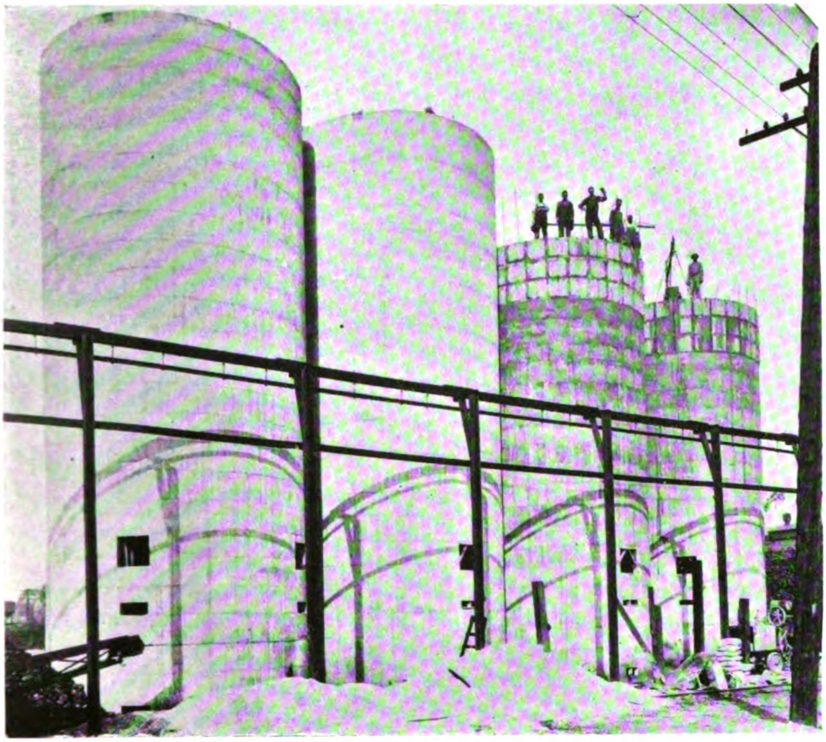


FIG. 145.—TWO THREE-COURSE OUTFITS OF "METAFORMS," SHOWING HOIST AND DISTRIBUTOR.

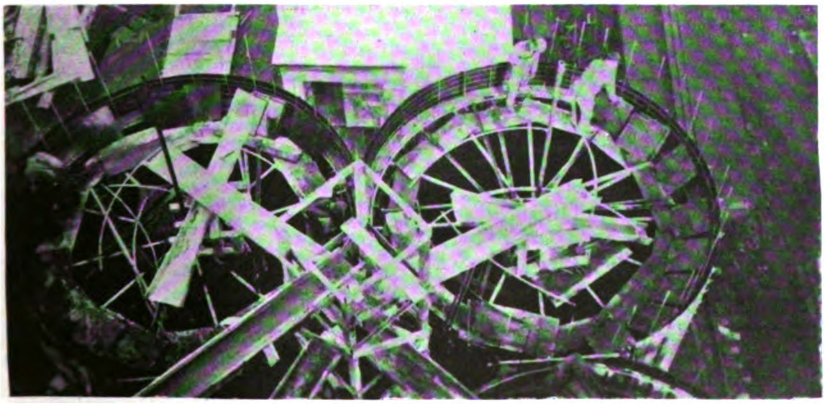


FIG. 146.—GRAIN BINS BEING BUILT UP TOGETHER WITH INTERLOCKING STEEL FORMS.

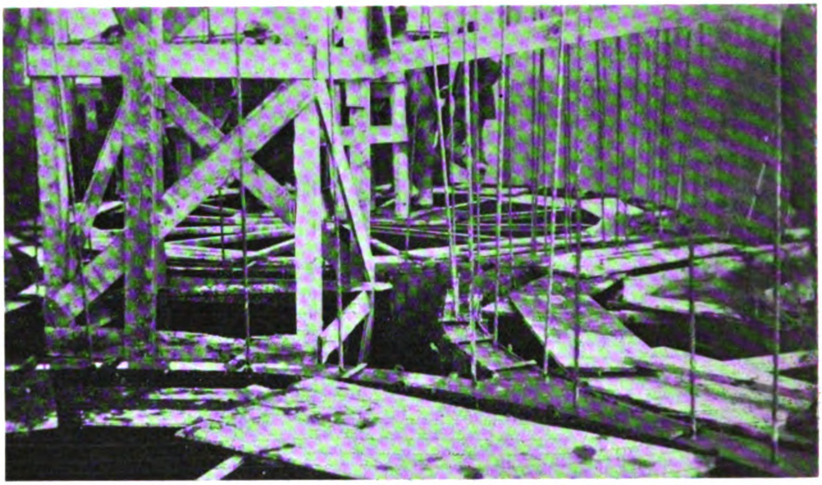


Fig. 147.—Forms at Connections of Bins illustrated above.

Cost.—The cost of placing and stripping circular steel forms is about the same as given for light wall forms, the operations being similar.

Concrete Piles Driven when Three Days Old.

Some rapid concrete piling has been carried out at the new jetty of Messrs. G. and T. Earle's Melton Works, near Hull, notwithstanding delays due to the frost.

Ordinary Trent gravel and sand were used with rapid-hardening Portland cement in the proportions of 4 : 1, 5 : 1, and 6 : 1. Piles were driven at the respective ages of 7, 7, and 9 days, and the manufacturers claim that these times have been improved upon. The piles were 12 in. by 12 in. cross-section, 30 ft. long, reinforced with four bars ¾-in. diameter, with ¼-in. stirrups at 9 in. centres, using a 35 cwt. ram falling 39 in. to a ¼ in. set.

To speed up the work some of the piles were cast using calcium chloride in the mixing water to the extent of 2¾ per cent. of the weight of cement. Piles made from 4 : 1 concrete were then driven at the age of three days. No failures occurred in the whole batch of seventy piles.

Concrete Cylinders in Quay Work.

An example of the application of ferro-concrete cylinders to quay work has been carried out at the Royal Victoria Docks, where the Port of London Authority is making big improvements for the meat trade. Included in the scheme is a new concrete quay 740 ft. long and 73 ft. wide on a series of 69 piers. Each of these consists of a concrete cylinder (5 ft. 6 ins. in diameter, vertically and circumferentially reinforced) containing a group of concrete piles surrounded with mass concrete hearting. The cylinders were moulded on shore with special ends for jointing purposes. A total length of 2,250 ft. was required, and in order to carry out the work with the necessary speed rapid-hardening Portland cement was used. When ready the cylinders were lowered by specially designed gear to a prepared bed on the dock bottom, and inside each of them a group of ferro-concrete piles was driven, followed by the mass concrete. The main structure of the quay, resting on these piers, carries the crane track and moorings and also the southern half of the main shed containing the meat conveyors.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	6
Thames ballast	,,	10	6
Broken brick (¾ in.)	,,	11	6
Best British Portland Cement	per ton 58s. to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	,, 100s. to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £20 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
5/16 in. to ½ in. Rounds	,,	10	9
⅜ in. Rounds	,,	11	0
¼ in. Rounds	,,	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do	do.	in foundation	per yard cube	48	6
Do.	do.	in columns	,, ,,	53	6
Do.	do.	in beams	,, ,,	53	6
Do.	do.	in floor slabs 4 in. thick	per yard super	5	8
Do.	do.	in floor slabs 6 in. thick	,, ,,	8	5
Do.	do.	in floor slabs 9 in. thick	,, ,,	12	3
Do.	do.	in walls 6 in. thick	,, ,,	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
,, 5/16 in. to ½ in.	,,	21	5
,, ⅝ in. to 2⅞ in.	,,	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	,, ,,	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	,, ,,	1	1½
Do. do. as last, in narrow widths	,, ,,	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	,, ,,	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

ALTOFTS.—*Road.*—The U.D.C. proposes to construct a road on the Hanby Avenue estate.

ATCHOP.—*Concrete Bridge.*—A reinforced concrete bridge is to be built at Atcham, at an estimated cost of £50,000.

BELFAST.—*Stand.*—At a cost of £10,000, the Celtic Football Club proposes to erect a concrete stand to accommodate 8,500 persons.

BELTON.—*Bridge.*—The Lindsey C.C. proposes to spend £7,500 on the construction of a bridge at Pilfrey.

BILLINGHAM.—*Houses.*—The U.D.C.has applied for permission to erect 100 houses.

BOSTON.—*Bridges.*—The Holland C.C. proposes to spend £5,114 on the construction of bridges.

BRADFORD. —*Concrete Houses.*—The T.C. proposes to erect 402 concrete houses.

BRADFORD.— *Roads.*—The Engineer has been instructed to prepare plans for the construction of roads from Apperley Lane to Station Road, Esholt; from King's Road to Otley Road, Hollins Hill; and a bridge at Apperley Bridge.

BRENTFORD.— *Houses.*—The U.D.C. has applied for sanction to a loan of £98,315 for the erection of 135 houses.

BRIGHTON.—*Houses.*—The Corporation is considering a scheme for the erection of 420 houses at North Moulscombe.

BROADSTAIRS.—*Road.*—A 60-ft. road is to be constructed from Edge End Road to the junction of Green Lane and Fairfield Road.

BUCKHAVEN.—*Houses.*—The T.C. proposes to build 300 houses.

CARDIFF. — *Bridges.* — The sum of £36,868 is to be spent on the construction of bridges by the Corporation.

CARLISLE.—*Houses.*—The Corporation proposes to build 100 houses on the Longsowerby estate.

CARLISLE. — *Houses.* — The C.C. is seeking sanction for the construction of 100 houses on the Longworthy estate.

CLYDEBANK.—*Concrete Houses.*—The T.C. proposes to erect 170 concrete houses at West Kilbowie, at an estimated cost of £72,500.

COATBRIDGE.—*Houses.*—The Corporation proposes to build 500 houses.

COVENTRY.—*Concrete Bridge.*—A reinforced concrete bridge is to be erected over the railway level crossing. The cost is estimated at £55,000.

COVENTRY. — *Houses.* — The Corporation has applied for sanction to a loan of £114,000 for housing purposes.

CROYDON.—*Houses.*—The T.C. has applied for permission to erect 520 houses.

EAST LINTON.—*Road.*—The sum of £70,000 is to be spent on the construction of a by-pass road.

EDMONTON.—*Houses.*—The U.D.C. has instructed the Engineer to prepare plans for the erection of 500 houses. The scheme is estimated to cost £453,800.

EPSOM.—*Reservoir.*—The U.D.C. proposes to spend £16,500 on the construction of a reservoir.

EXETER.—*Roads.*—The Surveyor has been instructed to prepare plans for the construction of roads on the Hamlin Farm estate.

FALMOUTH.—*Dock.*—A 600-ft. graving dock is to be constructed at Falmouth.

HASTINGS.—*Concrete Groyne.*—A concrete groyne is to be constructed at Marina, at a cost of £2,350.

HEATH TOWN.—*Bridge.*—The County Surveyor has been instructed to prepare plans for the construction of a bridge over Wolverhampton Road.

HEBBURN.—*Houses.*—The U.D.C. has applied for permission to erect 77 houses.

HENDON.—*Concrete Road.*—A 20-ft. concrete carriageway is to be constructed at Edgwarebury Lane.

HERNE BAY.—*Sea Wall.*—The U.D.C. has applied for a loan of £15,000 for the construction of a concrete sea wall.

HULL.—*Concrete Wall.*—The sum of £1,500 is to be spent on the construction of a concrete wall at the Ferens boating lake.

LISBURN. — *Concrete Roads.* — The U.D.C. has under consideration a scheme for the construction of concrete roads, at a cost of £35,000.

LIVERPOOL.—*Concrete Bridge.*—A reinforced concrete bridge is to be built at Queen's Drive, Mossley Hill. The cost is estimated at £5,358.

LLANILAR. — *Bridge.* — The Aberystwyth R.D.C. proposes to erect a bridge over the Ystwyth, at an estimated cost of £550.

LOUGHBOROUGH.—*Houses.*—The Housing Committee recommends the Corporation to erect 200 houses.

LUTON.—*Concrete Houses.*—The T.C. is considering the question of erecting concrete houses.

Maidstone.—*Houses.*—The T.C. has purchased a site on which to build 400 houses.

Nelson.—*Houses.*—The Corporation has applied for a loan of £50,000 for the construction of 100 houses on the Marsden estate.

Oldham —*Houses* —The T.C. is considering a scheme for the construction of 304 houses.

Poole.—*Houses.*—The Corporation has applied for sanction to erect 200 houses.

Portsmouth.—*Sea Defence Works.*—The Surveyor has been instructed to prepare plans for sea defence works at Clarence Beach.

Port Talbot —*Houses.*—The T.C. is negotiating for the purchase of 4,628 acres of land for housing purposes.

Queensferry.—*Bridge.*—The M.T. is to inquire into a proposal for the construction of a bridge over the Firth of Forth at Queensferry.

Ramsgate.—*Road.*—A road is to be constructed from Dumpton Railway Station to East Cliff.

Rough Close.—*Reservoir.*—The Staffordshire Potteries Water Board has instructed the Engineer to prepare a scheme for the construction of a reservoir at Meir Heath.

Scawthorpe.—*Houses.*—The Bentley U.D.C. proposes to build 144 houses at Scawthorpe.

Scotswood.—*Bridge.*—The C.C. is considering the question of building a bridge over the River Tyne.

Seaham. — *Roads.* — The U.D.C. has asked for sanction to a loan of £15,247 for the provision of roads on the Carr House estate.

Seaton Sluice.—*Sea Wall.*—The Northumberland C.C. proposes to erect a sea wall at Seaton Sluice.

Stockport.—*Road.*—The T.C. has submitted a scheme to the M.T. for covering the River Mersey from Mersey Square to Lancashire Bridge and constructing an 80-ft. road. The cost is estimated at £200,000.

Thetford.—*Concrete Wall.*—The T.C. has applied for a grant for the construction of a concrete wall to protect the north-east bank of the River Ouse. The cost is estimated at £391.

Thornhill.—*Bridge.*—The Dewsbury Corporation has applied for a loan of £4,000 for the construction of a bridge over the canal at Slaithwaite Road.

York.—*Houses.*—The T.C. has applied for a loan of £201,571 for the erection of 406 houses.

Tenders Accepted.

Birmingham.—The T.C. has accepted the tender of Messrs. Wilson Lovatt & Sons, Ltd., for covering the Erdington reservoir with reinforced concrete.

Bradford.—*Concrete Houses.*—The T.C. has recommended for acceptance the tender of Messrs. Henry Boot & Sons, Ltd., at £449 each, for the construction of 402 concrete houses.

Burnley.—The T.C. has accepted the tender of Messrs. Wellerman Bros., at £4,859 8*s.* 3*d.*, for the construction of reinforced concrete tar and liquor tanks at the gasworks. Other tenders submitted were: W. and J. Symes, £5,231 7*s.* 7*d.*; F.C. Construction Co., £5,909; Peter Lind & Co., £6,998 6*s.* 4*d.*; Rainey Bros., £5,700; B. Smith & Son, £5,800; J. Byrom, £6,929 18*s.*; R. and T. Howarth, £5,220; M. and J. W. Heap, £5,470; Smith Bros., £5,655 11*s.*; Matthews & Mumby, £6,340; Gray's Ferro-Concrete Co., Ltd £6,163 18*s.* 9*d.*

Burnley.—The Corporation has accepted the tender of Messrs. Rainey Bros., Ltd., Barrow-in-Furness, at £2,083, for the construction of a reinforced concrete raft.

Gosport.—*Concrete Houses.*—The T.C. has accepted the tender of Messrs. John Laing & Son, Ltd., for the construction of 200 concrete houses.

Leafield, Chipping Norton.—*Reservoir.*—The R.D.C. has accepted the tender of Messrs. Rowell & Sons, Chipping Norton, at £597 13*s.* 4*d.*, for the construction of a reinforced concrete reservoir.

Liverpool.—*Concrete Bridge.* — The Corporation has accepted the tender of Messrs. R. and T. Howarth, Rochdale, at £5,358 15*s.* 3*d.*, for the construction of a reinforced concrete bridge at Briardale Road, Mossley Hill.

Liverpool.—*Piers and Silos.*—Messrs. Christiani & Nielsen have secured the contract for the construction of concrete piers and silos for Messrs. F. A. Jones, Ltd., of Liverpool.

NEW MALDEN.—*Concrete Houses.*—The U.D.C. has accepted the tender of the Triangular Construction Co., Ltd., at £14,750 10*s.*, for the erection of 30 concrete houses.

POLPERRO.—*Bridges.*—The Liskeard R.D.C. has accepted the tender of Messrs. J. Wimpey & Co., at £1,990, for the demolition of two bridges and culverts, and the construction of two reinforced concrete bridges. Other tenders submitted were: Christiani & Nielsen, £2,049 10*s.*; Mitchell & Son, Ltd., £2,200.

SCARBOROUGH.—*Concrete Road.*—The T.C. has accepted the tender of Messrs. T. Jarran & Son, Scarborough, at £3,439, for the construction of concrete carriageways in Londesborough Road.

SOUTHALL.—*Concrete Cottages.*—The U.D.C. has accepted the tender of the Triangular Construction Co., Ltd., at £21,735, for the construction of 45 concrete cottages.

WIMBLEDON.—The T.C. has accepted the tender of Messrs. Peter Lind & Co., at £1,070, for concrete foundation work at the generating station.

New Company Registered.

CEMENT PRODUCTS, LTD. (211,223). Registered January 21. Concrete, tile and artificial stone makers, etc., now carried on at Basford as "The Basford Stone and Tile Co." Nominal capital: £3,000. Directors: F. Hodson, The Bungalow, Park Valley, Nottingham; H. H. Goodall, Devonshire Avenue, Beeston; L. Parkin, 19 Rufford Road, Nottingham; H. S. Lord, 11A Carnarvon Road, W. Bridgford.

Recent Patent Applications.

238,548.—F. Schlagintweit: Moulding ferro-concrete beams.

240,376.—J. H. Doble and W. T. Appleton: Shuttering for casting walls *in situ.*

240,719.—A. R. Prior and R. T. Hargreaves: Cavity-blocks and apparatus for their manufacture.

240,761.—C. Hutchins and J. R. Morris: Collapsible cores for concrete walls.

241,034.—J. Herrmann: Concrete blocks.

241,440.—M. Edslev: Concrete posts.

241,731.—E. M. Lane. Concrete blocks.

242,116.—R. Meeg-Sarssen and A. K. Bu. Casting concrete poles and masts in an upright position.

242,446.—J. J. Hoogewerff. Concrete construction.

242,596.—Austro-American Magnesite Co.: Mixing cement and fibrous material.

242,811.—C. F. Ward: Struts for reinforced concrete.

242,835.—H. E. Harris: Reinforced concrete floors.

243,410.—T. Rigby: Manufacture of cement.

243,468.—H. F. Smith and C. H. Tuckwell: Hollow concrete floors, beams and slabs.

243,483.—Sir E. W. Moir: Concrete walls.

243,876.—U. B. Voisin: Alumino-calcareous hydraulic cement.

243,981.—E. B. Wilkinson: Manufacture of concrete blocks.

244,012.—W. A. Gavin: Monolithic concrete structures.

244,144.—Chatwood Safe Co., Ltd., and H. S. Bruckshaw: Reinforced concrete.

244,351.—C. W. Dorkin (jun.), P. McGinty and H. Bradshaw: Core for casting hollow concrete walls.

244,504.—J. E. Cardell: Concrete paving.

244,549.—E. J. C. Chapman and A. Fowler: Concrete walls.

244,608.—S. E. Saunders and J. Winfield: Cementing piles or layers of wood.

244,617.—M. Galke: Reinforced concrete floors.

244,671.—K. P. Billner: Concrete material.

244,838.—A. R. Leelands and G. Damry: Concrete piles.

244,913.—P. G. Blake: Means for attaching wires, etc., to concrete posts.

244,963.—K. P. Billner: Concrete.

244,973.—W. J. S. Duften, T. Obank, W. J. Obank and L. S. Obank: Artificial stone.

245,007.—D. H. Stent: Concrete walls.

245,866.—S. W. Burley: Manufacture of cement, and kilns for use therein.

245,975.—E. Van Putten: Shuttering.

Trade Notices.

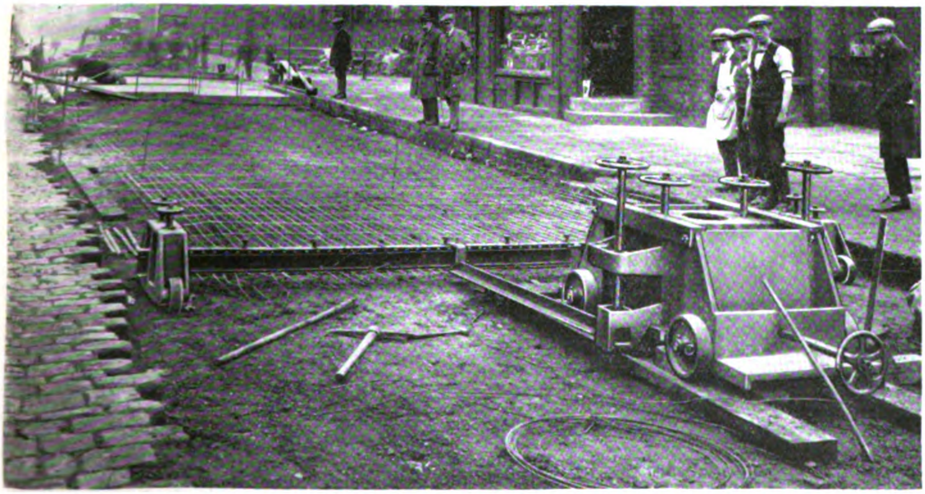
A Reinforcing Machine.

We have received particulars of a new machine for the placing and securing in position of steel wire rods or fabric used in the construction of reinforced concrete roads or structures. The method is especially applicable to roads, which may be reinforced with either single or double layers of reinforcement. The machine is claimed to place any kind of reinforcement designed to meet a particular case, such as extra steel over sewers or trenches and on weak ground.

As the reinforcement is tightly stretched, it cannot be displaced by workmen walking on it, and thus the factor of uncertainty as to the actual position of the steel in the concrete is eliminated. The steel is given an initial tensile stress of up to 1,000 lbs. per sq. in.

One of the main advantages claimed for the system is that the Engineer or Surveyor is not tied down to standard weights and sizes of reinforcing fabric, but can design his own fabric to almost any specification as regards quality of steel, spacing and weight.

The patentee is Mr. John W. Liversedge, of Leeds.



Reinforcing Machine.

Light-Weight Concrete.—In a reference to the new "expanded" concrete just put on the market by Messrs. Christiani & Nielsen, in our January issue, the coefficient of thermal conductivity which penetrates in one hour through 1 sq. ft. of the material (1 cement to 3 sand), 1 ft. thick, weighing about 40 lbs. per cubic foot, should have been given as 0·9; while with material weighing about 65 lbs. per cubic foot the coefficient should have been given as 0·13.

Concrete Mixers.—The Ransome Machinery Co. (1920), Ltd., of 46 Victoria Street, S.W.1, have received an order from Sir Robert McAlpine & Sons, for four of their "Welterweight" concrete mixers, which have an unmixed batch capacity of 12 cu. ft., and are the largest size of the three well-known Ransome concrete mixers, the "Welterweight," "Lightweight," and "Featherweight."

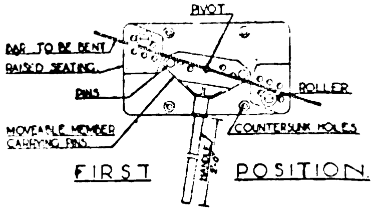
New Floor and Road Surface.—Fine metal particles, selected for their durability, are the basis of a new concrete floor surface just put on the market by the François Cementation Co., Ltd., of Bentley Works, Doncaster. The material, known as "Betonac," is supplied in 2-cwt. bags, and is mixed with Portland cement, and sand, if necessary, on the site. We are informed that tests have shown that concrete made with this material is 2·2 times as durable as granite, and five times as durable as ordinary concrete under abrasive tests. It will withstand water pressures up to 3,000 lbs. per sq. in., and does not absorb oil. If desired, sand may be added ; this, of course, reduces the strength, but may be economical in positions where extreme durability is not essential. A 2-cwt. bag of "Betonac" requires 1 cwt. of Portland cement, and this mixture will cover 7 yards super ½ in. thick. The material is supplied in different grades, and by blending these a rough finish may be obtained which will remain throughout the life of the floor. We have seen samples of "Betonac" floor surfaces cast quite recently, which appear to justify the claims made on its behalf. The manufacturers have issued a booklet dealing with the material, which will be forwarded to any of our readers who are interested.

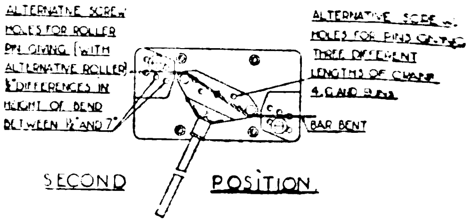
Sir William Arrol & Co. (Swansea), Ltd.—This structural works, formed by Sir William Arrol & Co., Ltd., of Glasgow, and Messrs. Baldwins, Ltd., was opened up in 1923, and some idea of the contracts already carried out may be obtained from an attractive booklet just issued by the firm. These contracts include heavy steel work for all kinds of structures, such as bridges, transporters, tanks, railway stations, etc. The up-to-date works of the firm are also fully illustrated, and three colour plates by Mr. E. A. Cox are included.

Patent Victoria Stone Co., Ltd.—We have received from the Patent Victoria Stone Co., Ltd., of Salisbury House, Finsbury Circus, E.C.4, a desk blotting pad for 1926. This is one of the best and most strongly produced pads of its kind we have seen, and in addition to the blotter it contains a side-pocket with memoranda slips and a diary for 1926.

New Bar-Bending Machine.

We illustrate herewith a new bar-bending machine which has been put on the market by the Indented Bar and Concrete Engineering Co., Ltd., of Queen Anne's Chambers, S.W.1. As will be seen, it is a portable machine, which makes the two bends usually required in slab bars in one operation, and in the case of smaller bars it will bend more than one at a time. The depth of the bend can be altered by an adjustment of the machine for bars to fit any thickness of slab between 2½ and 9 inches. Three different lengths of crank (4 in., 6 in., or 9 in.) are obtained by altering the position of the pins. Bars up to ⅝ in. diameter can be bent cold.




ALTERNATIVE SCREW HOLES FOR ROLLER PIN GIVING (WITH ALTERNATIVE ROLLER) 5 DIFFERENCES IN HEIGHT OF BEND BETWEEN 1½" AND 7"
ALTERNATIVE SCREW HOLES FOR PINS GIVING THREE DIFFERENT LENGTHS OF CRANK 4, 6 AND 9 INS
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A correspondent writes to ask for the names and addresses of firms specialising in equipment for foundation work equivalent to concrete piling without the concussion of a "monkey."

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

APRIL 1926 **VOL. XXI No. 4**

CONCRETE SERIES No1

TWENTY-FIRST YEAR OF PUBLICATION

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CONCRETE
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Volume XXI. No. 4. LONDON, APRIL, 1926.

EDITORIAL NOTES.

Proportioning Concrete.

OUR American contemporaries of recent date show that a remarkable interest is being taken in the question of the proportioning of concrete. Since the results of the tests made by Professor Abrams at the Structural Materials Research Laboratory were published a few years ago, the subject has been taken up by contractors and others interested and, as one of our contemporaries puts it, " The old régime of letting 1 : 2 : 4 take care of everything has gone by the board." In a recent issue of " Engineering News Record " it is stated that thinking engineers and contractors are moving beyond the theoretical consideration of the scientific control of concrete mixes into practical applications that promise both economy and efficiency. This progress has been slow but indications now are that it is being materially accelerated and concrete practice is going to be benefited by the acceleration.

For years concrete was proportioned on a purely arbitrary basis. Beginning on the assumption that for a balanced mix, where the sand filled the voids in the stone, the relation of the fine to coarse aggregate should be one to two, strength was assumed to be a function of the amount of cement so that a 1 : 2 : 4 would be stronger than a 1 : 3 : 6 mix. Water could be added according to the taste and fancy of the mixer. Soon, however, came theories of aggregate grading, all looking toward increased density of mix and reduction of voids, but all the time water content was neglected and arithmetical proportioning accepted. About seven years ago, Professor Abrams discovered an ordered relation between strength of concrete and the ratio of the water to the cement in the concrete, a relation that persisted through all kinds of aggregate and all kinds of mixes, provided the resultant concrete was of a consistency that would readily slide from mixers, fill forms, and penetrate rod meshes, all without segregation or visible water. It was also found that the economy to be gained from the grading of aggregate was quite separate from the strength obtained from a proper water-cement ratio. There followed, therefore, the radical proposal that instead of requiring the contractor to proportion his concrete by some arbitrary measure of cement and stone, that the engineer merely specify the water content to guarantee the desired strength and let the contractor put in as little stone as he could actually work with, in such proportions as to ensure a workable mixture. Theory indicated, what some experience has since demonstrated, that the resulting concrete would be uniform and strong and economical, which both the contractor and the engineer wanted.

This is the stage to which the most advanced of the workers in this field have now arrived.

" More and more," says our contemporary, " the theories and methods they advocate are beginning to penetrate into the denseness of custom which still controls the vast majority of concrete mixed. Only slowly can be overcome the inertia of the man who prides himself on knowing all about concrete because he has been placing it the same way for twenty years. Let it not be thought that the new methods mean the routinising of concrete making. Rather the contrary, for we have here the substitution for the rote of 1 : 2 : 4 the preliminary study and constant supervision of the trained observer and tester. For every job there has to be careful study of available aggregate to determine just what mix is the most economical and what is the proper water-cement ratio to be used with it. And that having been established there is required throughout the manufacturing process a precision in measurement and care in mixing and placing unknown under the old r[illegible]me of 1 : 2 : 4."

Effect of Hot Cement on Paper Bags.

In certain countries, notably in Germany, the custom has spread of delivering cement in paper sacks, which are non-returnable. These sacks have advantages and disadvantages compared with the older jute sacks, and experiments have lately been carried out to discover the action of cement, at the time when the sacks are filled, on various kinds of paper. The results, to date, of these experiments were reported recently in " Revue des Materiaux de Construction et de Travaux Publics."

Frequently it happens that the temperature of the cement when being filled into sacks lies between 60 deg. C. and 80 deg. C., especially if the cement mill is working to full capacity. As a result, the water contained in the paper is almost completely dried out.

Three kinds of paper have been tested, under the following conditions : (*a*) As received at the cement mill, (*b*) immediately after its withdrawal from an oven where it had been heated for five hours to 80 deg., (*c*) after drying for five hours at 80 deg. and subsequent exposure to air of 65 per cent. humidity for twenty-four hours, (*d*) after similar drying but exposure for six days to air of 65 per cent. humidity, (*e*) after drying for five hours and exposure to damp air for thirteen days.

The general conclusions arrived at were as follows : (1) Paper dried for five hours at 80 deg. did not contain more than 15 per cent. of its original moisture ; (2) Such dried paper when exposed to the damp air reabsorbed almost all the moisture which had been driven off in the oven ; (3) Paper dried at this temperature lost its elasticity ; (4) When allowed to reabsorb moisture the paper's resistance to tearing was increased at first beyond its original value when first delivered at the mill, but after thirteen days' exposure to moist air the resistance was reduced to 65 per cent. of its original value ; (5) Paper dried at 80 deg. becomes very brittle and is very sensitive to damage by mechanical treatment so long as it has not reabsorbed a quantity of moisture equivalent to its original moisture content ; (6) Paper sacks filled with hot cement require careful handling.

New Type of Retaining Wall.

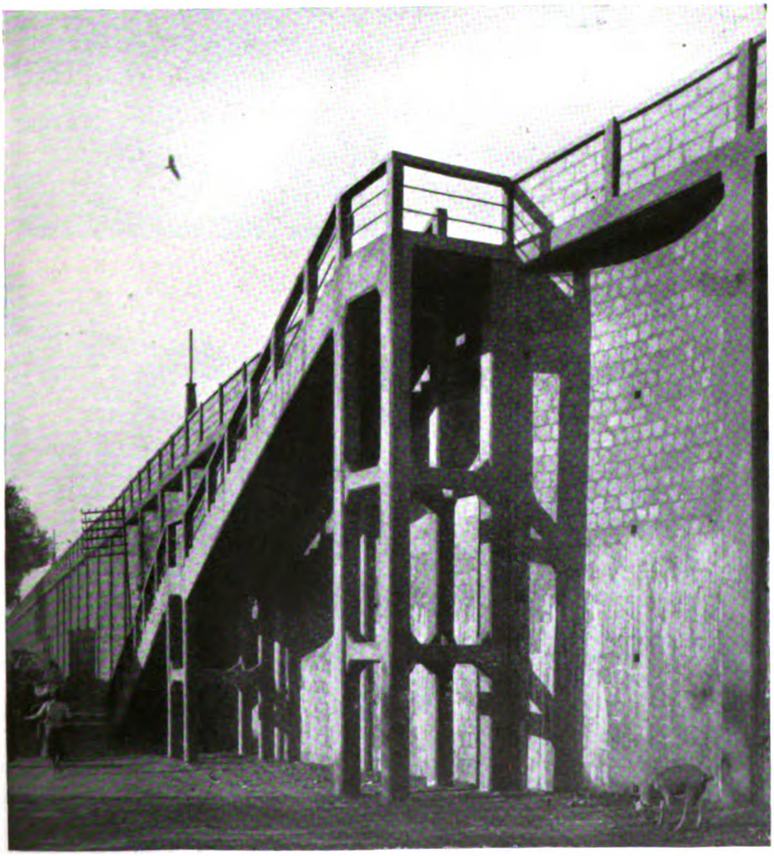
By R. P. MEARS, B.A., A.M.Inst.C.E.

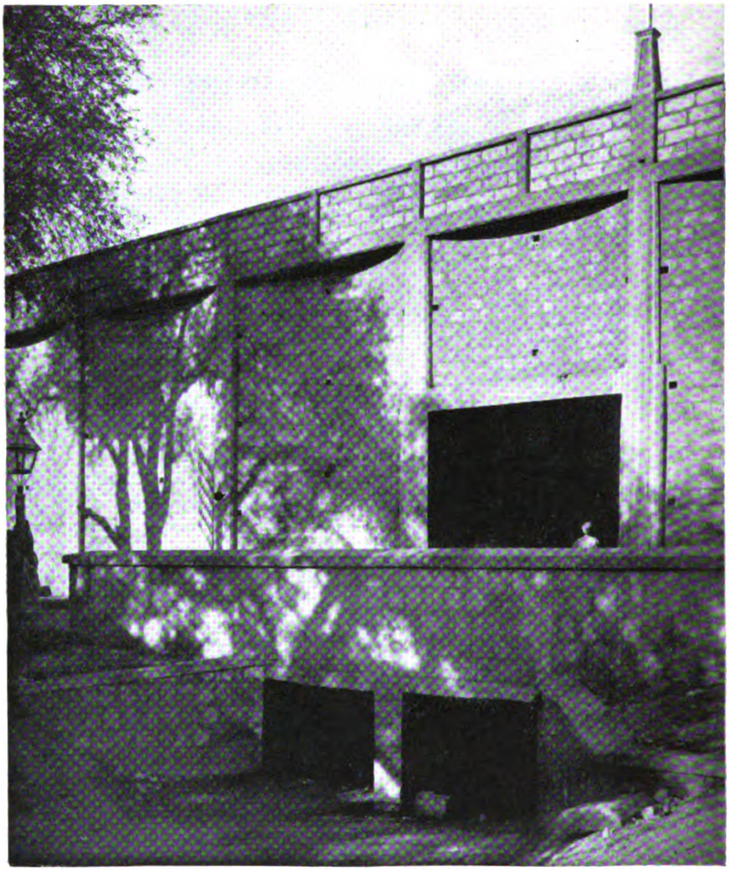
The accompanying photographs and drawing show the design and construction of a novel type of retaining wall lately built at Ahmedabad, India, in connection with the approach roads to a railway overbridge.

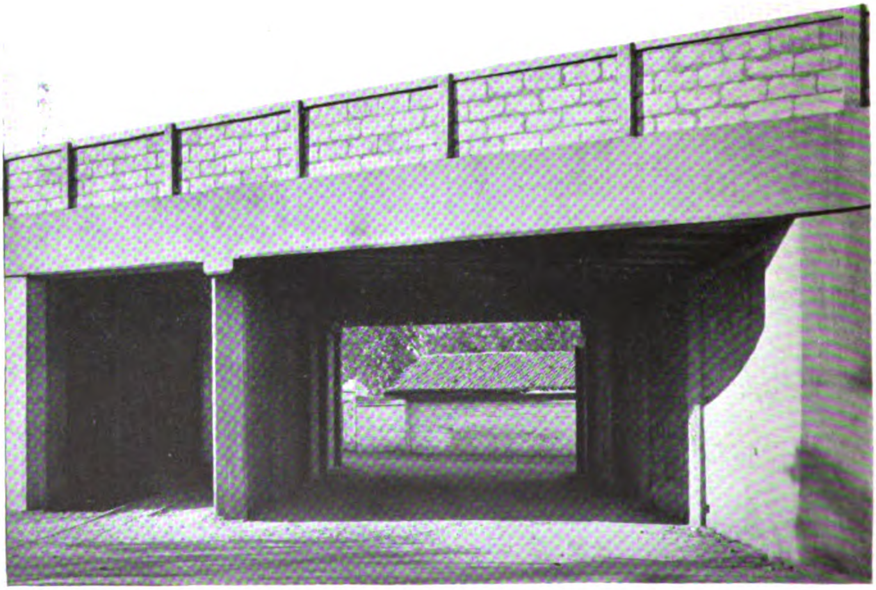
The drawing shows in section, plan, and elevation the design adopted, which consists of a horizontally-arched wall constructed in concrete blocks on a foundation beam. These horizontal arches are built between skewbacks (clearly shown in the photographs) cast on a vertical counterfort. This vertical counterfort is constrained at its base by the foundation beam, and in rear by the diagonal ties securing it to the anchor beam behind. Road filling is subsequently filled up behind these walls bearing on the anchor beam and preventing overturning. Forward movement is prevented by both foundation and anchor beams being filled in solid against the earth on the side exposed to movement.

This type of design has been found to be very much cheaper than any of the standard text-book methods of retaining wall construction. The bulk of the work consists of block walling in a lean mix involving no *in situ* centering or expensive reinforcement.

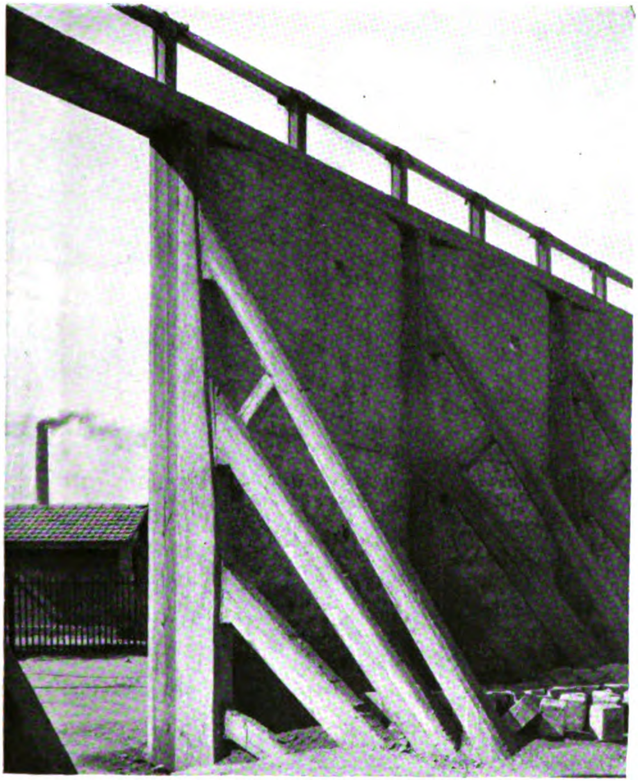
In the reinforced concrete members the bulk of the construction occurs low down in the foundation and anchor beams, which are readily filled from ground level without shuttering. It is only the

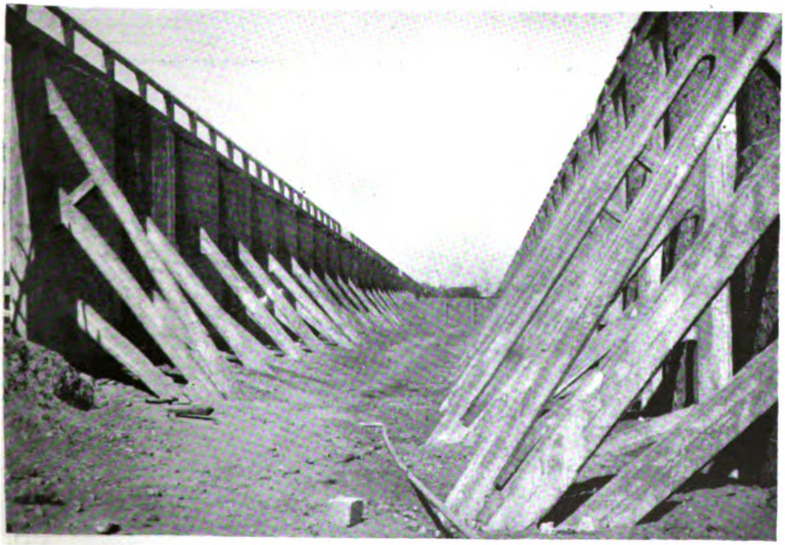






New Type of Retaining Wall.



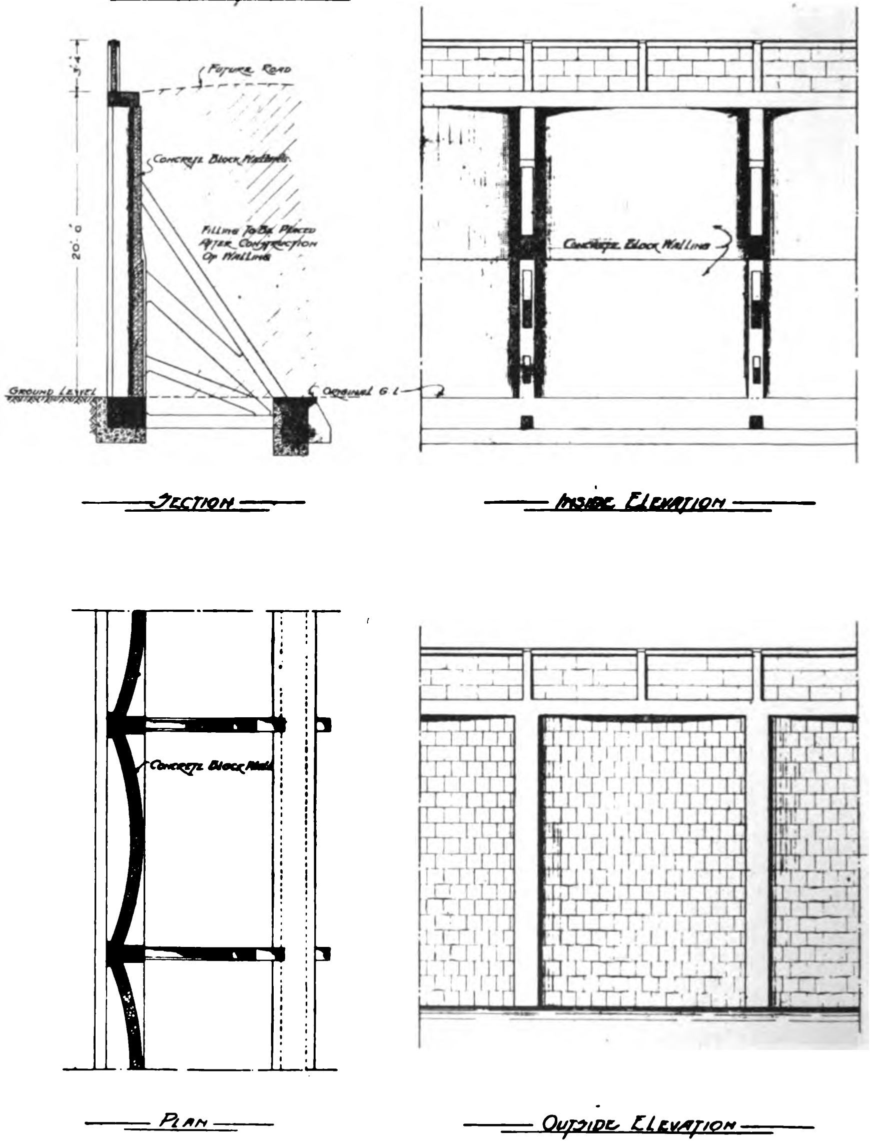


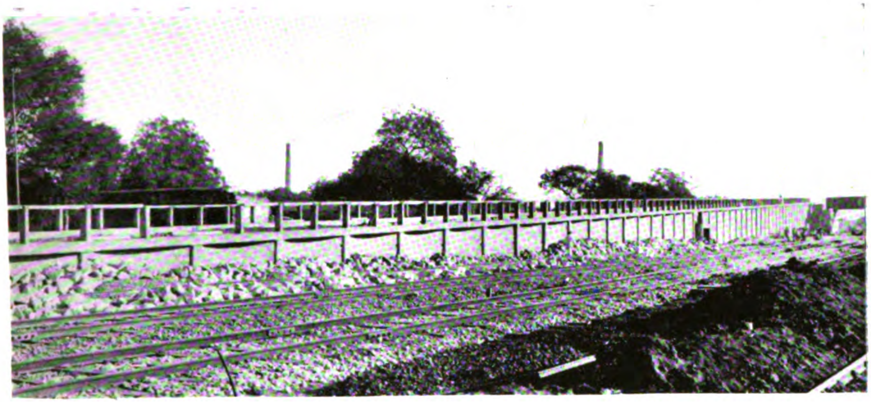
New Type of Retaining Wall.

TYPE RETAINING WALL

TO SUIT A HEIGHT OF ABOUT 20 FEET

SCALE. – 4 FEET TO AN INCH



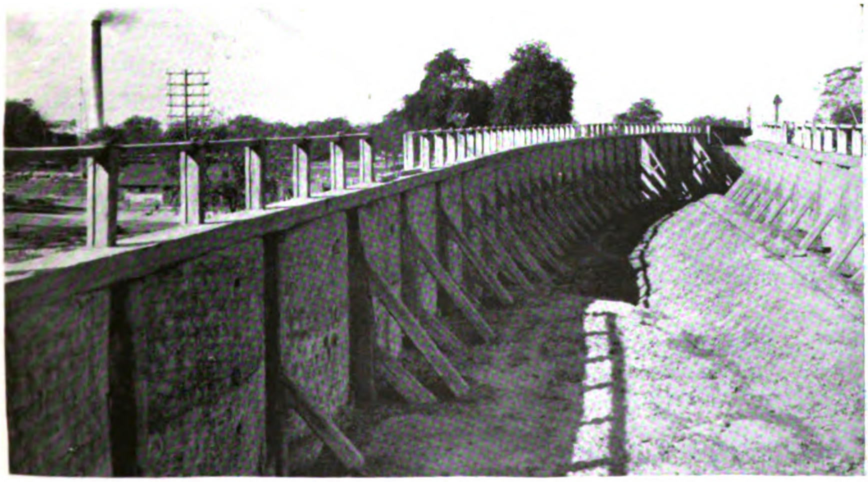


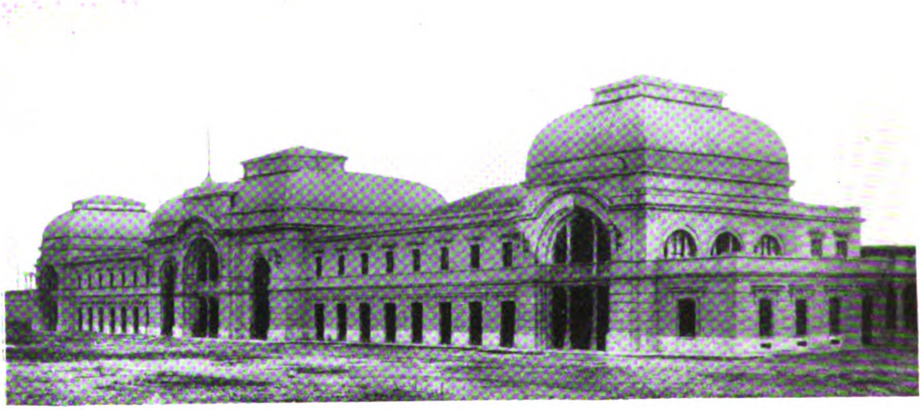
diagonals and vertical member that require good casing. Very little scaffolding is necessary. This construction is very rapid, and over a mile of this type of walling was carried out in a year.

In India the relative prices of brickwork and rubble masonry vary greatly in different localities, but can generally be obtained within the low price of sixpence to ninepence per cubic foot for a class of work sufficiently good for a gravity retaining wall; consequently with cement costing about £4 to £5 per ton delivered, and imported steel at about 14*s.* per cwt. (delivered), it is very difficult to design a concrete retaining wall to compete against local masonry or brickwork in lime mortar. Reinforced concrete inclusive of centering and all charges would represent generally from 4*s.* to 5*s.* per cubic foot, a figure probably relatively very much higher than would occur in England.

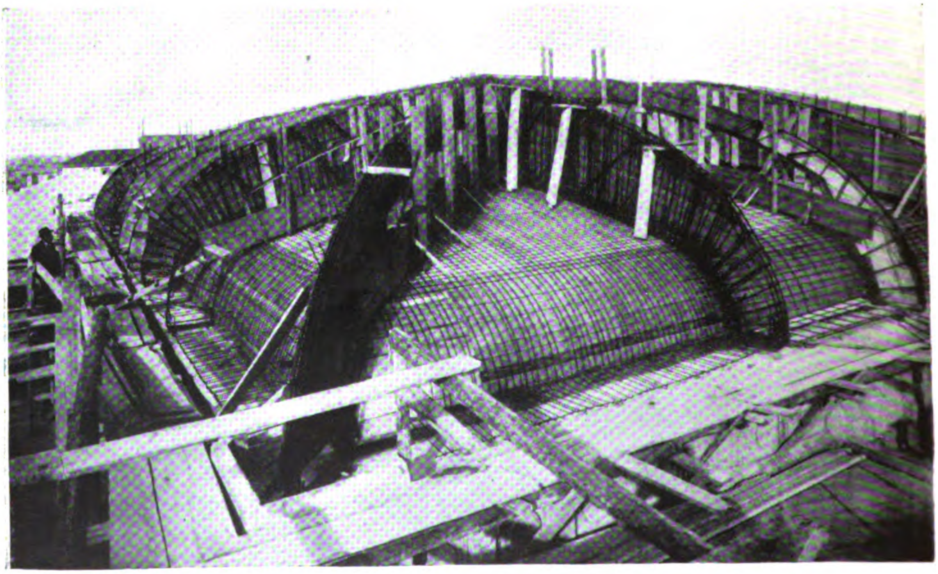
Even under these adverse conditions this type of wall may be built in India for a clear 10 to 15 per cent. below the cost of a gravity wall in local materials and in half the time. In England its financial advantages would probably be much greater.

The work as shown was carried out by Messrs. J. C. Gammon, Ltd., engineers and contractors of Bombay, for whom the author is chief engineer. A patent (No. 240017 of 10/12/25) has been obtained in England for this type of retaining wall.





General View.



Construction of Cupola.

Railway Station at Verona. (*See p.* 301.)

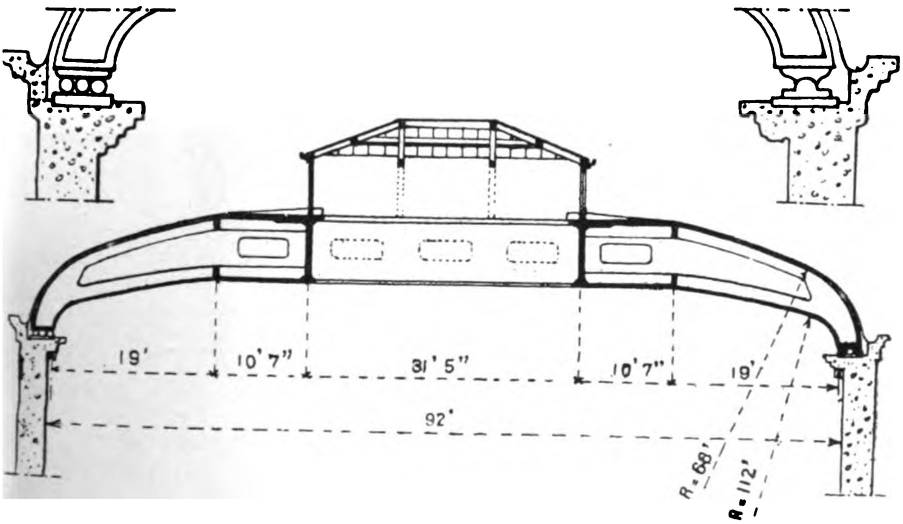
Reinforced Concrete Cupolas at Verona.

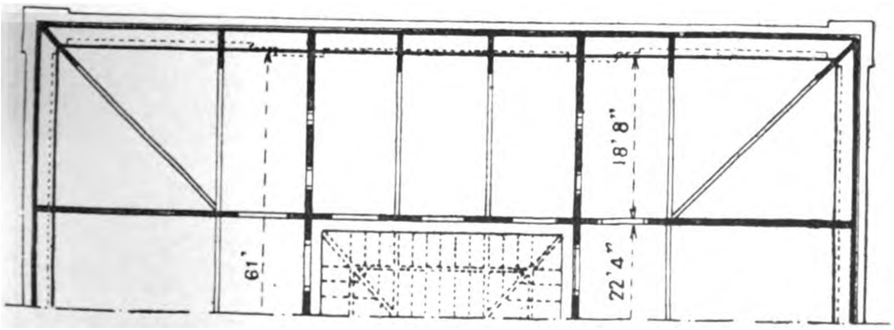
Some interesting details have been incorporated in the construction of three cupolas on the new railway station at Verona. As will be seen in the illustrations, the permanent way is on the first-floor level, the ground floor being used for booking-office, waiting-rooms, etc. The photographs and drawing refer to the centre cupola, which is the largest, measuring 92 ft. by 62 ft.; the other two measure 50 ft. by 33 ft.

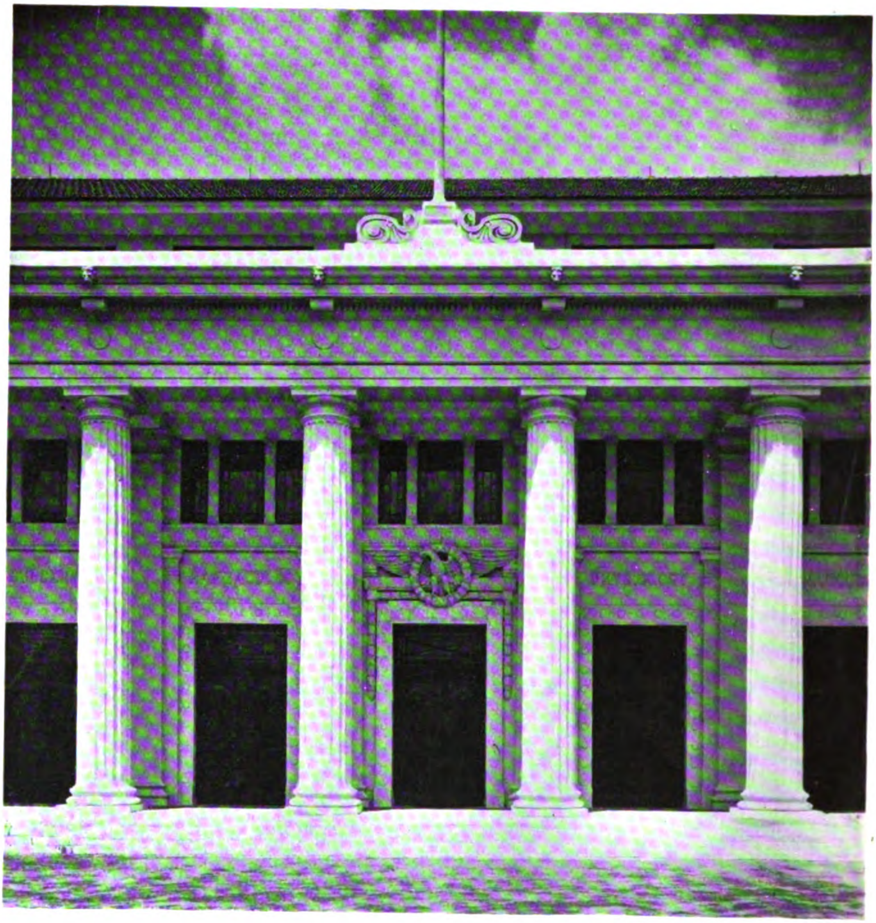
The method of construction is clearly shown in the section. The ends of the beams are not embedded in the walls, but rest upon roller joints which allow of lateral movement due to temperature changes and also of any turning movement that might arise from the same cause. The stresses in the arches have been determined on the assumption that the whole of the arches form one monolithic body.

Calculations for stability are based on a maximum load of 20 lbs. per sq. ft., a horizontal wind pressure of 20 lbs. per sq. ft., and a maximum temperature variation of 90 deg.

The ceilings are in reinforced concrete, while the outer covering consists of asbestos-cement slates.







New Medical College, Singapore:
Main Entrance.

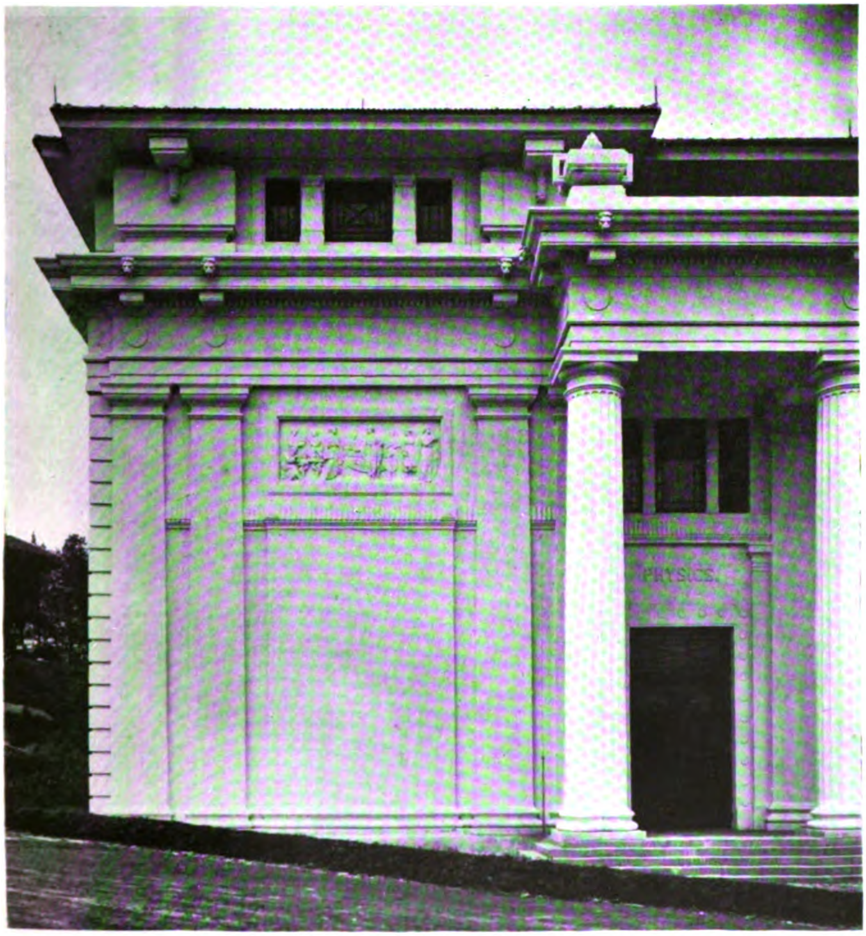
Concrete Medical College at Singapore.

King Edward VII Medical College has been erected as part of the scheme for the building of a new General Hospital in Singapore.

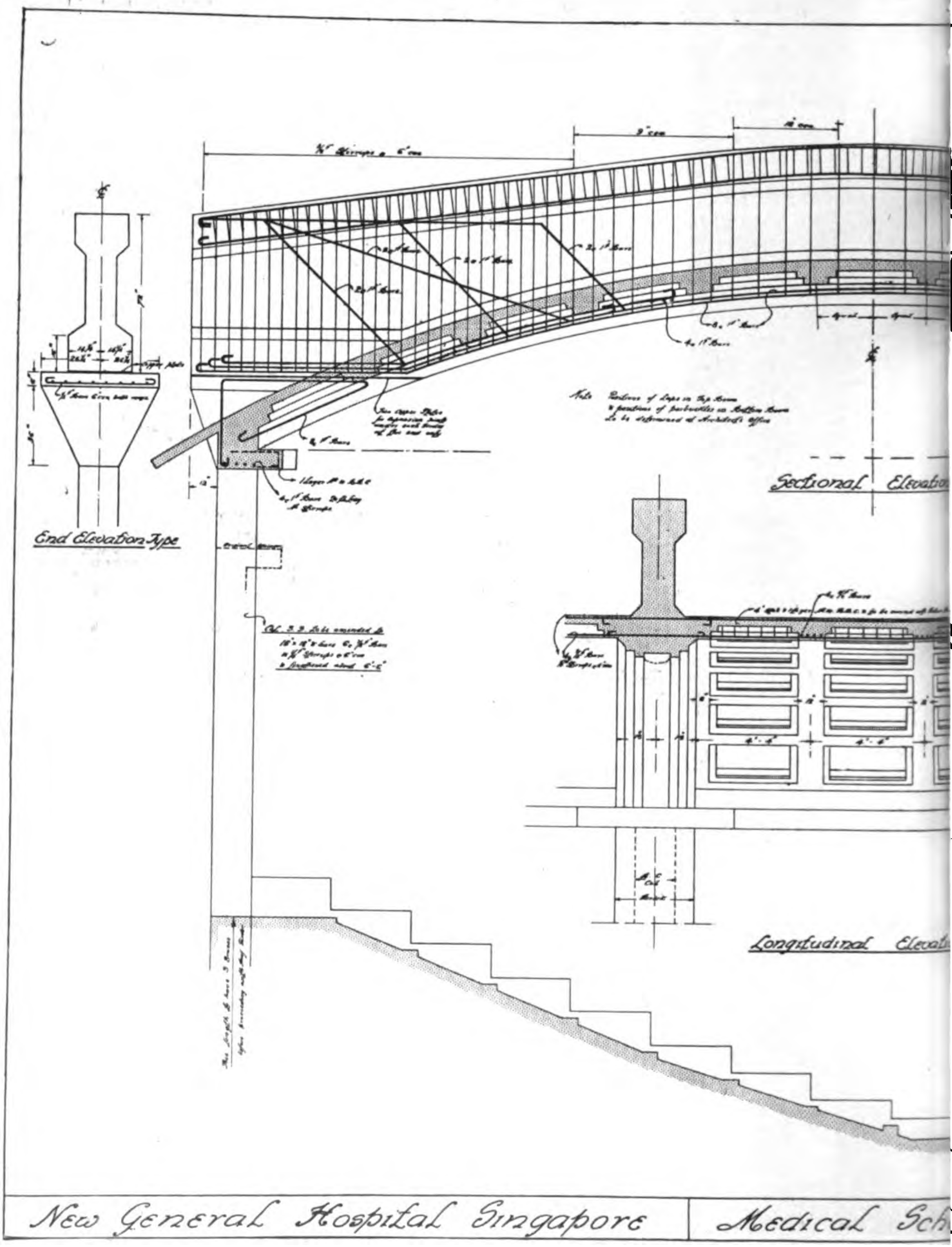
It is a reinforced concrete structure of three stories. The special architectural features are the Doric colonnade on the principal façade and the classical groups of sculpture representing the teaching and practice of Medicine and Surgery in the end features.

The main entrance is marked by heavy relief scupture, making a handsome centre doorway in the main façade. The building houses the following chairs: Medicine, Surgery, Pathology, Biology, Gynæcology, Anatomy, Chemistry and Physics, for which there are specially fitted laboratories and lecture rooms.

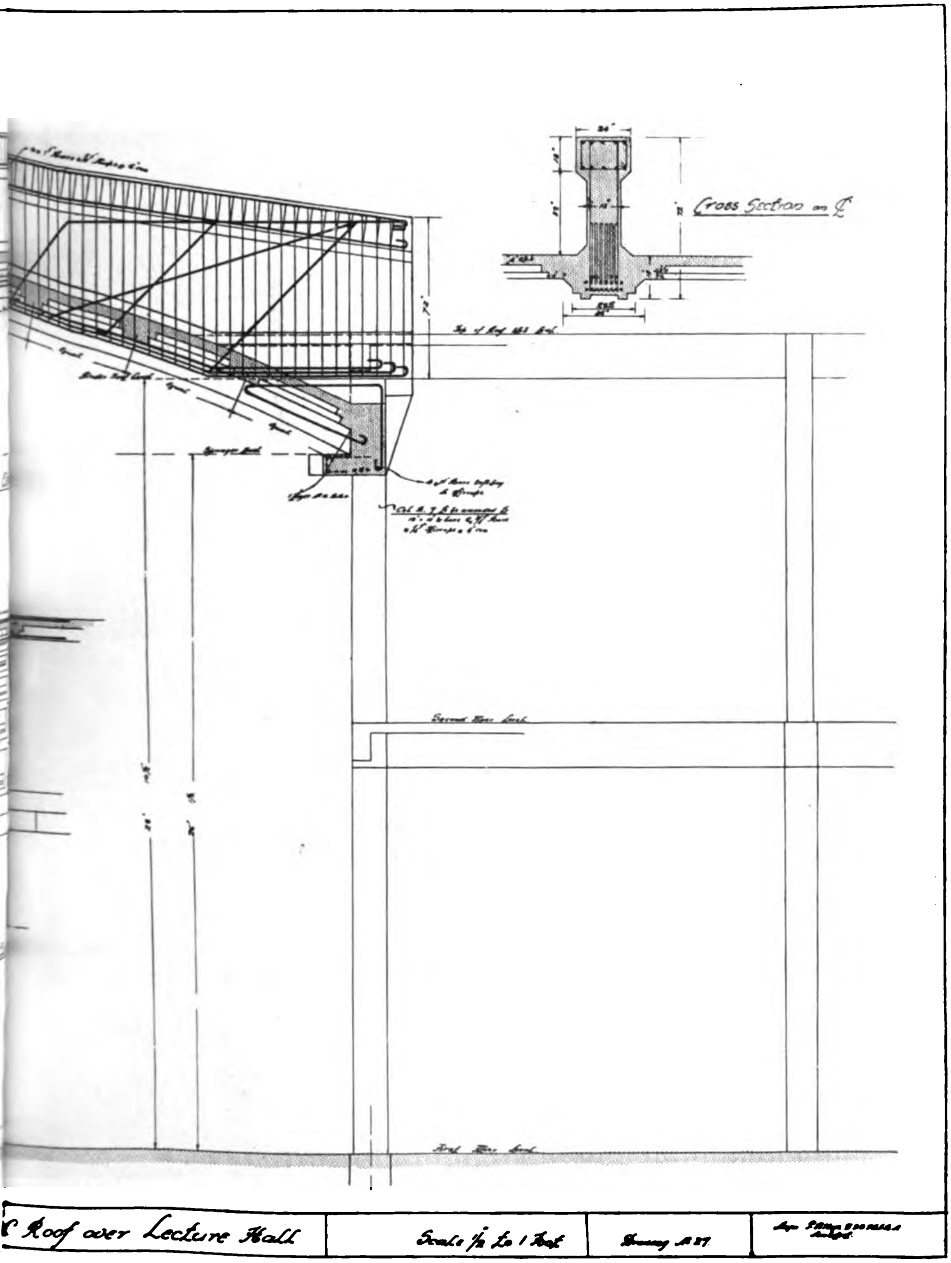
The lecture theatre has seating accommodation for 200 persons on a raised auditorium and a coffered ceiling of reinforced concrete spanning 49 feet. In the reinforced concrete design for the roof over the lecture theatre, and due to the coffered ceiling, the engineer had to adopt the I type of girder with the ceiling suspended from the bottom flange of the



New Medical College, Singapore: Detail of Main Façade.

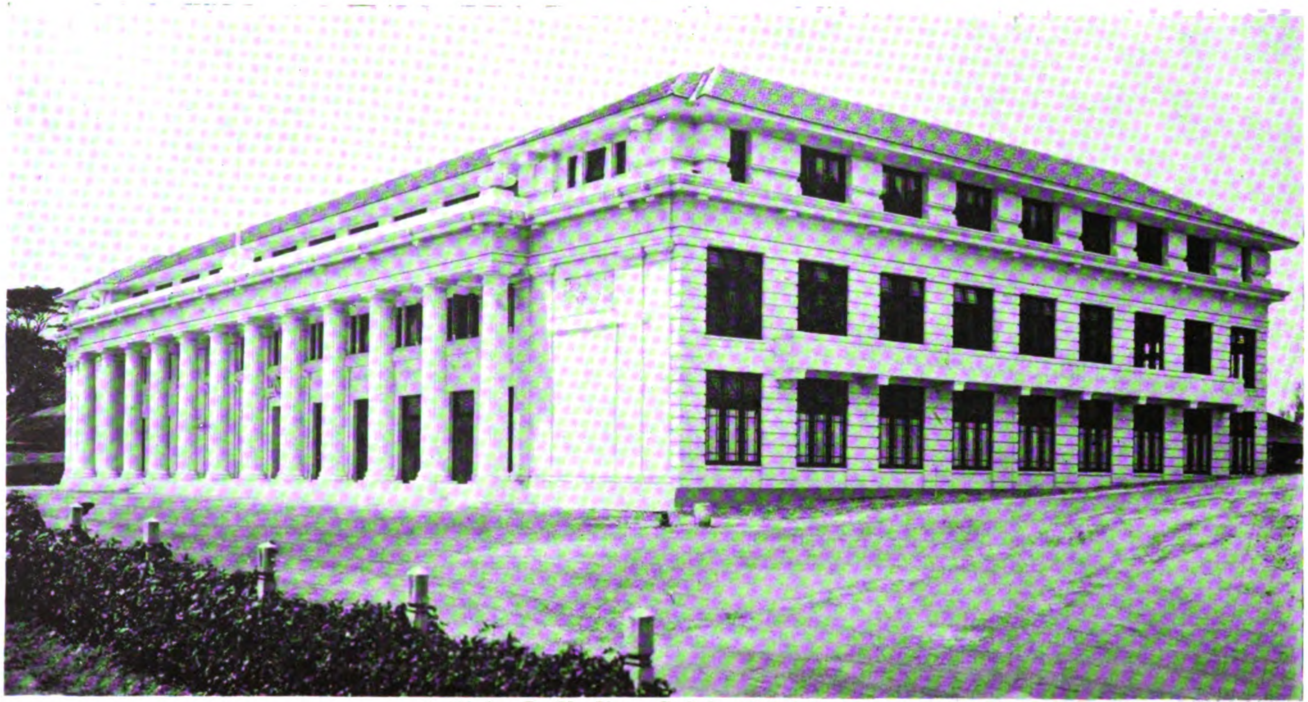


Details of Construction of New G



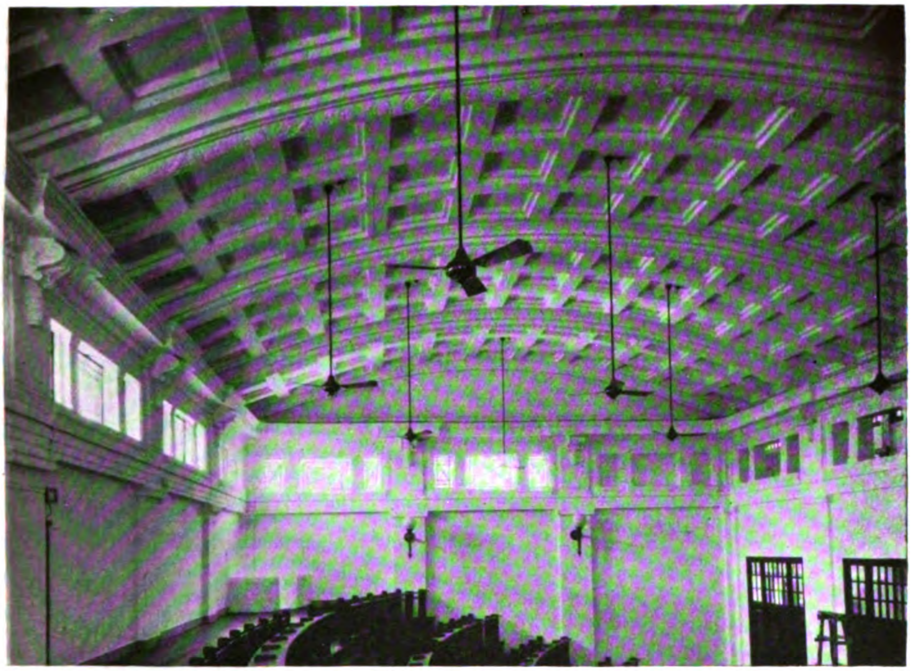
Major P. H. Keys, D.S.O., F.R.I.B.A., Architect; Mr. J. Sharpe Elliot, Engineer.

tal Medical School, Singapore.



Major P. H. Keys, D.S.O., F.R.I.B.A., Architect; M. J. Sharpe Elliot, Engineer.

New General Hospital Medical College, Singapore.

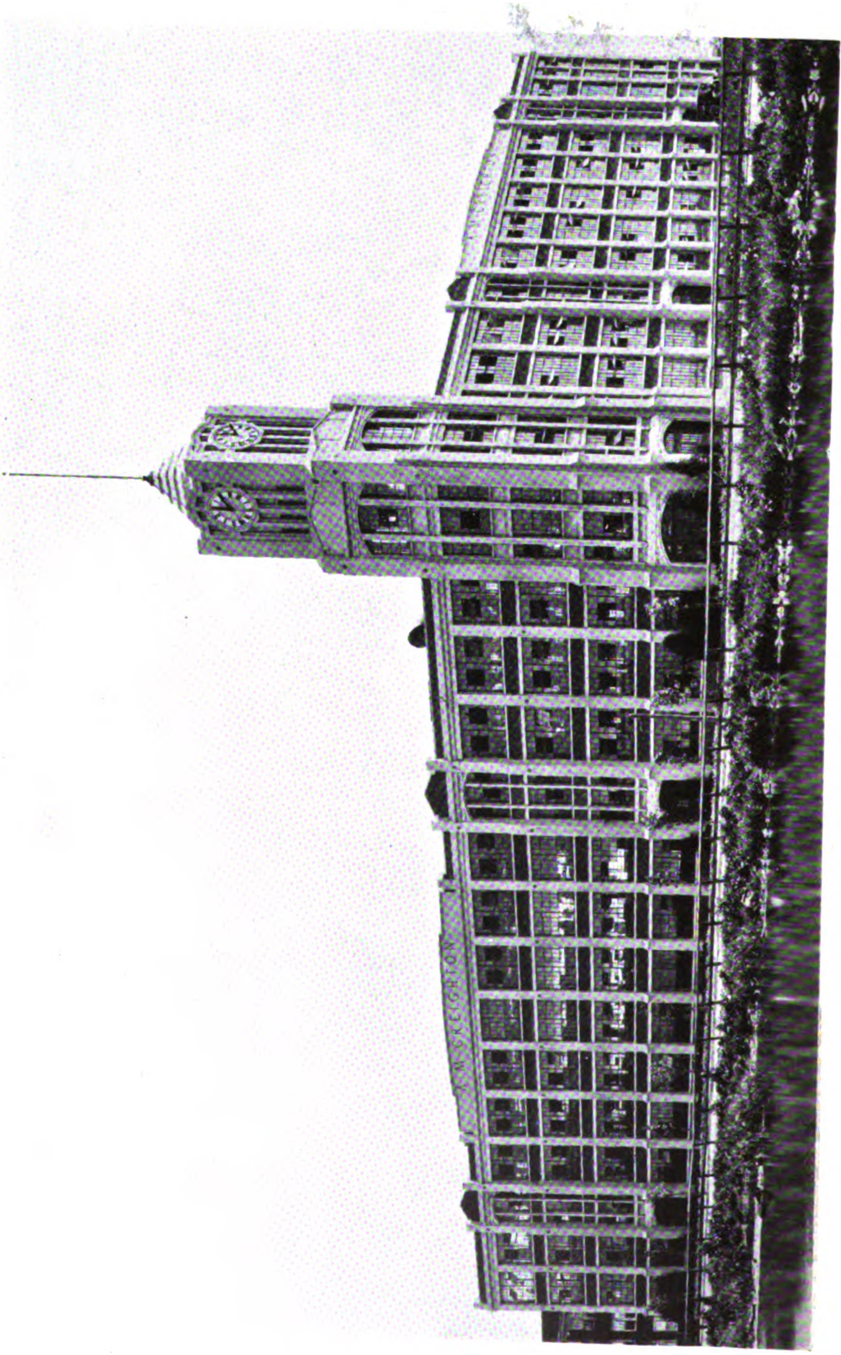


New Medical College, Singapore: Roof of Lecture Theatre.

girder. The reinforced concrete work was designed and carried out by Mr. J. Sharpe Elliot, Concrete Engineer to the Department, and drawings of the chief points of interest are given on pp. 304–5.

The sculpture and reliefs were modelled and cast in special concrete of marble and white cement by R. Nolli, an Italian sculptor residing in Singapore. This work is particularly good both in design and execution. The Doric columns to the façade and all the ornamental work to the exteriors and interiors are precast in granite concrete.

The architect is Major P. H. Keys, D.S.O., F.R.I.B.A., to whom has also been entrusted the work of the new General Hospital, the Mental Hospital, and the new General Post Office, all in Singapore. The contractors were Messrs. J. C. Gammon, Ltd., of Bombay and Singapore.



Factory Building at Lynn, Massachusetts.

(Reinforced Concrete Frame and Floors.)

[*Mr. H. F. Kellogg, Architect.*

Ultimate Strength and Elastic Constants in Compression for Granite Concrete.

By W. D. Womersley, M.A., B.Sc., A.M.Inst.C.E.

THE following is an account of a series of tests carried out to determine as accurately as possible the elastic constants of the usual forms of concrete in reinforced concrete work. For this purpose an hydraulic press of 150 tons capacity was arranged to take specimens 2 ft. in diameter by 4 ft. long, and to vary the stress by water loading the accumulator up to 550 lbs. per sq. in. on the concrete. The size of the specimens was decided upon with a view of eliminating lack of homogeneity as far as possible, and from this point of view the results are satisfactory. Two preliminary specimens were made, using flint gravel aggregate, and these preliminary experiments were briefly outlined in *Concrete and Constructional Engineering* for September, 1924.

The first scheme of tests was for 1 : 2 : 4 concrete with granite sand and aggregate, and five series of specimens were made with the solid ingredients (cement, sand and aggregate) constant and the water varied from the minimum to the maximum possible. The quantities of water required were determined by mixing test-cubes on the bench. In the batch with the least water only a slight moisture appeared on ramming the material into the cube moulds, but by slapping vigorously with a trowel when the mould was full sufficient water could be brought to the surface to allow the upper face of the cube to be dressed off evenly. The maximum quantity of water was such that the liquid kept breaking away from the foot of a piled mass and any increase in the quantity would have made hand manipulation almost impossible on the slightly-inclined concrete floor. The three intermediate mixes were to be uniformly spaced between the maximum and minimum.

Measured volumes of cement, sand, and aggregate were weighed out and thereafter the whole of the proportioning was by weight on account of the unsatisfactory nature from a comparative point of view of the volumetric method. The solid ingredients for the various mixtures were proportioned as follows: Cement, 3 cu. ft. (240 lbs.) ; sand, 6 cu. ft. (570 lbs.) ; aggregate, 12 cu. ft. (1,080 lbs.). The water was as given in Table I.

TABLE I.—PROPORTIONS OF WATER.

	A	B	C	D	E
Weight in pounds	200	185	170	155	140
Volume in cubic feet	3·20	2·96	2·72	2·48	2·24
Proportion of water to solid ingredient by weight	0·1058	0·0979	0·0900	0·0820	0·0741
Proportion of water to solid ingredient by volume	0·1522	0·1408	0·1294	0·1181	0·1066
Proportion of water to cement by weight	0·833	0·771	0·709	0·646	0·584

The main idea underlying the tests was to determine the effect of the variation of the quantity of mixing water on the elastic constants. Subsidiary to this, sets of thirty 4 in. cubes were made up in conjunction with each large specimen, and these were to be crushed in groups of six at ages of 30, 60 and 90 days, 6 months, and 1 year, to ascertain the effect on the ultimate strength.

At the time of writing the first set of elasticity tests has been completed and the cubes have been crushed up to ages of 6 months. It is hoped to make a further set of elasticity tests when the material is about 1 year old, and to communicate the results together with the completion of the cube tests in due course.

Materials Used.

Cement.—Quick-hardening cement of very similar chemical constitution to ordinary Portland cement was used and the following routine tests were made.

Fineness—

Residue on 76 mesh sieve . . .	0·27 per cent. by weight.
Extra Residue on 180 mesh sieve . .	3·60 ,, ,, ,, ,,

Each an average of three.

Setting Time in Minutes (Vicat Needles)—

Date . .	2.8.24	16.8.24	28.8.24	16.9.24	30.9.24
Initial . .	82	93	144	175	145
Final . .	155	193	265	310	263

Expansion (Le Chatelier)—

Average, 1·5 m.m. Maximum, 2·5 m.m.

Tensile Tests (each figure the average of 60 briquettes)—

Neat Cement.		3 to 1 Sand.	
7 days	28 days	7 days	28 days
938 lbs. per sq. in.	955	597	649

A further set of tensile tests is in progress at various ages up to 1 year. The figures obtained up to the present time are as under :

Time. Days.	Neat Cement. Lbs. per sq. in.	3 to 1 Sand. Lbs. per sq. in.	Time. Months.	Neat Cement. Lbs. per sq. in.	3 to 1 Sand. Lbs. per sq. in.
1	394	190	2	897	654
2	683	427	3	883	669
3	787	508	4	906	691
4	854	530	5	856	642
5	856	529	6	851	679
6	880	573	8	862	665
7	860	542	10	795	712
14	880	625	12	800	705
21	828	621			
28	902	669			

(*Each figure is the average of 6 briquettes. The weight of the cement was standardised at* 80 *lbs. per cu. ft.*)

Granite Sand and Aggregate.—This was from Leicestershire and a truck load containing 3 tons of sand and 6 tons of aggregate was obtained. Most of the material was dumped on the floor of the laboratory and turned and spread daily until quite dry. The quantities for the mixes were taken from the dumps, and no effort was made to arrange the various size particles. The sand was found to be graded from $\frac{1}{10}$ in. to dust and the aggregate from $\frac{3}{4}$ in. to $\frac{1}{10}$ in., as in the sieve analyses below.

Sieve Analysis of Sand (average of three)—

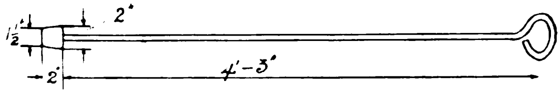
Pass 10 mesh sieve	84·0 per cent. by weight
,, 20 ,, ,,	49·1 ,, ,, ,, ,,
,, 30 ,, ,,	37·1 ,, ,, ,, ,,
,, 40 ,, ,,	28·5 ,, ,, ,, ,,
,, 50 ,, ,,	25·0 ,, ,, ,, ,,
,, 76 ,, ,,	18·4 ,, ,, ,, ,,
,, 180 ,, ,,	8·4 ,, ,, ,, ,,

Sieve Analysis of Aggregate (average of two)—

Pass 2 mesh sieve	73·5 per cent. by weight
,, 4 ,, ,,	26·2 ,, ,, ,, ,,
,, 10 ,, ,,	0·5 ,, ,, ,, ,,

(An "n" mesh sieve means n^2 holes per sq. in.)

The size of the holes in the various sieves has not been measured, but this can be done if necessary. The sand was standardised at 95 lbs. per cu. ft., and the aggregate at 90 lbs. per cu. ft. Void analyses were made of both sand and aggregate with the following results :—Voids in Sand, 43·2 per cent. by volume ; Voids in Aggregate, 44·1 per cent. by volume.



Rammer

Fig. 1.

Water.—The water was drawn from the town mains. It is of the hard variety and is pumped up from the chalk.

Method of Manufacture.

The cement, sand, aggregate, and water were weighed. The sand and cement were dry mixed first and then piled on to the aggregate, the whole being thereafter turned three times. After the last dry mix most of the water was added from a watering-can with rose, the pile being turned and raked meanwhile. The first wet turn was then made, the remainder of the water being added where needed. Two more wet turns were then made. After this, one man shovelled slowly into the mould, which was lined with oily paper, whilst three men rammed the material as it went in. Pauses were made about every 6 in. in the filling for extra ramming. The rammers were long bars with handles at one end and steel plug-shape pieces at the other (*Fig.* 1) and were very efficient. From first adding the water to finishing filling the mould took about 45 minutes in general (though "D" took about 1 hour and "E" was made in two mixes instead of one, and each mix took about 37 minutes). Whilst the mould was being filled ten 4-in. cubes were made of material taken from the heart of the mix. On the whole the cubes got more ramming than the large specimens. The cubes were taken out of their iron moulds the following day and placed under water in order to treat them all as nearly alike as possible. The mould was taken off the big specimen in 10 or 12 days, and the specimen taken to be stored near the testing machine a day later. The quick-hardening cement does not require any different treatment from ordinary Portland cement during mixing and casting; it seemed to behave in exactly the same manner.

The remaining twenty 4-in. cubes of each series were made up on the bench in batches of two or three as and when the moulds became available. The large mixes were made at intervals of roughly a fortnight, the actual dates being given in the setting-time tests for the cement. The manufacture of 4-in. cubes and the cement testing went on daily after the first large mix until finished. Five bags of cement (2 cwts. each) were obtained direct from the works on the morning the first specimen was made and stored in the laboratory, covered by tarpaulin until finished. A second load of six bags was then obtained to complete the remaining specimens.

Crushing Tests of 4-inch Cubes.—The cubes were bedded into the machine top and bottom with neat cement paste and tested immediately. The

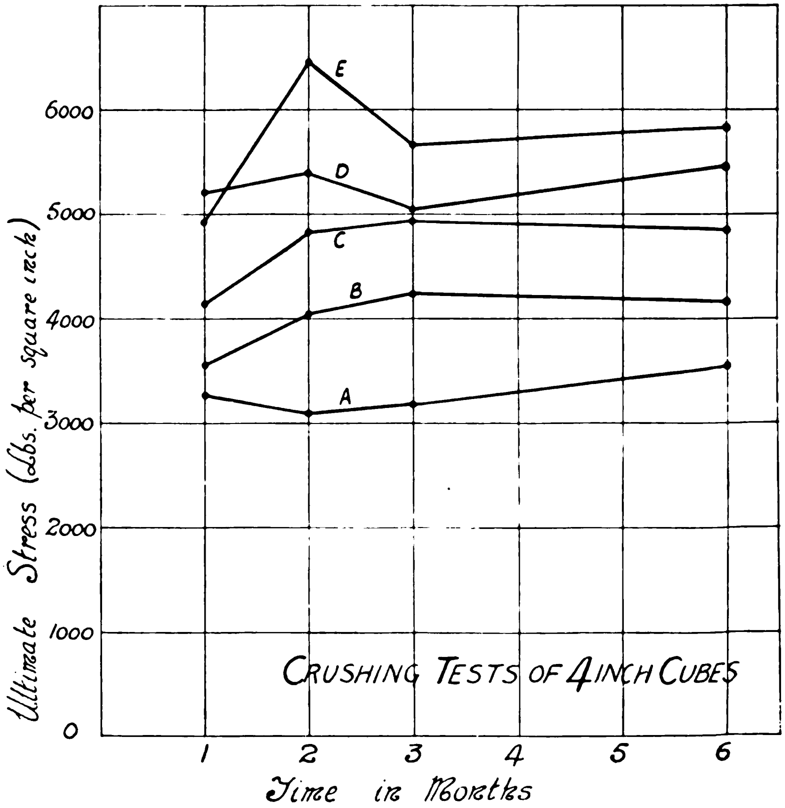


Fig. 2.

surplus cement was squeezed out on the application of the load and the cubes were then in perfect contact over the upper and lower surfaces with the platens of the 50-ton Buckton single-lever testing machine. The failure of the cubes was always of an explosive nature, two almost perfect pyramids with the upper and lower faces as bases being left, and sometimes similar pyramids were broken out from the sides. In future the shape of the test specimen is to be changed to a cylinder 4·37 in. diameter (to give 15 sq. in.) and 6 in. long. A larger specimen cannot be used on the machine.

The results of the crushing tests, as far as they have gone, are given in Table II, together with the averages. These latter are plotted in *Fig.* 2.

TABLE II.—CRUSHING TESTS OF 4-INCH CUBES (LBS. PER SQUARE INCH).

	Time in Days.	Cube No.						Average.
		1	2	3	4	5	6	
A	30	2790*a*	2920*a*	3015*c*	3240*d*	3545*c*	3980*d*	3250
	60	2910*b*	2950*b*	3050*b*	3140*b*	3220*a*	3240*a*	3085
	90	2790*b*	3000*a*	3090*b*	3130*a*	3400*b*	3650*b*	3180
	182	3110*c*	3120*a*	3520*b*	3700*c*	3860*b*	3990*a*	3550
B	30	3150*b*	3230*a*	3390*b*	3580*a*	3910*b*	3960*b*	3540
	60	3730*b*	3870*a*	3910*a*	3990*b*	4150*b*	4610*b*	4040
	90	3990*c*	4010*a*	4240*c*	4260*a*	4350*c*	4610*c*	4240
	182	3500*a*	4100*c*	4140*a*	4160*c*	4340*c*	4800*c*	4170
C	30	3810*b*	3890*b*	4200*a*	4210*a*	4250*b*	4510*b*	4145
	60	3980*a*	4470*c*	4980*c*	5070*c*	5090*a*	5300*c*	4815
	90	3790*a*	3830*a*	5070*c*	5320*c*	5450*c*	6100*c*	4925
	182	4480*a*	4670*d*	4870*c*	4890*d*	4930*a*	5230*c*	4845
D	30	4930*b*	4960*b*	5050*a*	5210*b*	5340*b*	5780*a*	5210
	60	3930*a*	4450*a*	5110*b*	6160*b*	6260*b*	6440*b*	5390
	90	3830*c*	4705*c*	5130*a*	5160*c*	5560*a*	5850*c*	5040
	182	5010*c*	5280*c*	5400*c*	5425*a*	5770*a*	5920*c*	5470
E	30	4060*a*	4350*a*	4580*a*	5040*a*	5460*a*	6100*a*	4930
	60	5010*b*	6230*b*	6800*b*	6810*b*	6900*b*	7000**b*	6460
	90	$4740c_3$	$5360c_2$	$5610c_1$	$5700c_2$	$5850c_3$	$6700c_1$	5660
	182	4460*a*	5630*d*	5740*d*	5940*a*	6480*d*	6730*d*	5830

Notes on Table II.—* This cube could not be broken. The small letters refer to cubes mixed on the same day. (*a*) is the mix from which the large specimen was made. The suffix figures in the case of the " E " cubes at 90 days refer to different mixes on the same day.

Elasticity Tests in Compression.

Calibration of Press.—A steel shaft 5 in. diameter was tested, with the extensometers fitted, in the machine. It was then placed in the press and the contractions noted for various pressures on the ram increasing from 0 up to the maximum and then decreasing to 0 again. The pressures were indicated by a new steel tube pressure gauge. From this experiment the actual load on the shaft was deduced corresponding to the various pressures both loading and unloading. These were slightly different on account of the friction at the ram packing.

Mounting Specimens in the Press.—The lower end of the specimen was quite plane on account of the bottom of the mould being a flat steel plate. No preparation was thus necessary and it was placed directly on a $\frac{1}{4}$-in. lead sheet laid on a 1-in. oak board on the base of the press. The upper end of the specimen was depressed towards the centre on account of the setting contraction being greater in the centre than round the edges. The edges are probably held up by friction between the concrete and the mould. The upper face was dressed with a thin cement grout and the upper platen of the press brought gently down on to it and left there until the cement had set. A $\frac{1}{4}$-in. lead sheet and a 1-in. oak board were then inserted above the specimen as at the lower end (*Fig.* 3).

Extensometers.—Heavy iron rings of rectangular section 1-in. thick by

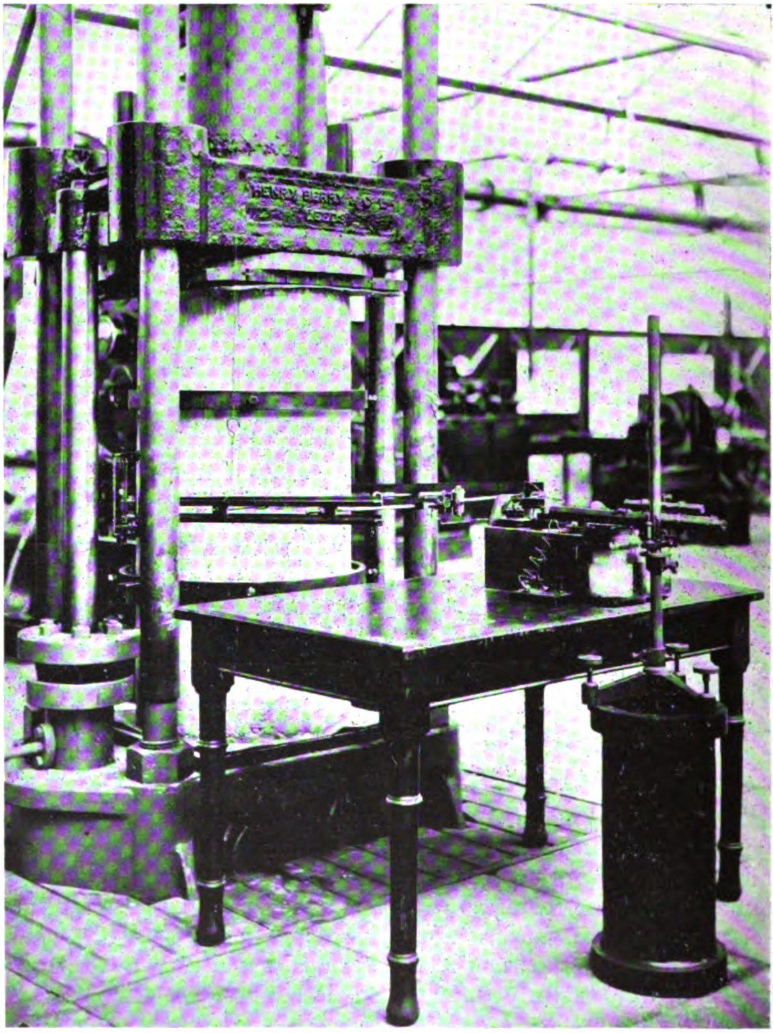


Fig. 3.

2-in. deep were clamped on to the specimen at 20-in. centres over the central length of the specimen. The attachment was by means of four roughened steel pads arranged at the extremities of two mutually perpendicular diameters. These pads were later replaced by hardened steel points, but without any apparent change in the results. The two extensometers were clipped to $\frac{3}{8}$-in. diameter bars bolted to the rings and arranged at the extremities of a diameter at 45 deg. to the diameters containing the fixing pads. The extensometers were thus operating on a length of 20 in. of the specimen. They were of the Landon type (*Fig.* 4), and have not previously been described or illustrated. They consist essentially of upper and lower blocks clipped to the specimen to be tested and with a ball and socket interconnection at the fulcrum rod. Contact at this point is maintained by a spring. Indication of changes of length of the specimen is given by the deflection of two flat springs initially arranged at just about the critical strut load, each with a piece of ivory attached. There are corresponding marks in these pieces of ivory which are brought into line by a graduated torsion head working on a differential screw. The screw has 40/50 threads per inch, so that the equivalent pitch is $\frac{1}{200}$th of an inch. The torsion head has 100 divisions around its periphery, and the lever ratio from the specimen to the indicator about the ball and socket joint is 2·5 : 1. Thus one division on the torsion head is equivalent to a change of length of the specimen of 2×10^{-5} in. In the given

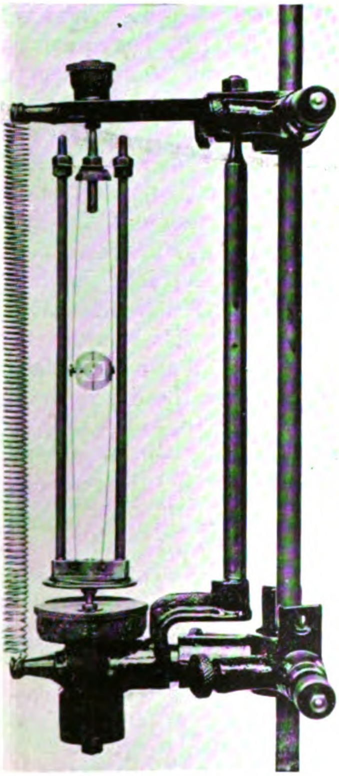


Fig. 4.

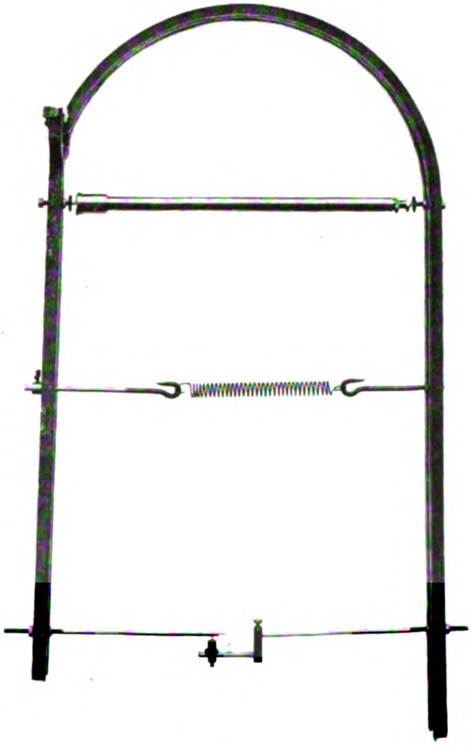


Fig. 5.

application, since the length of specimen producing changes is 20 in., one division represents a strain of 1×10^{-6}. The instrument is thus direct null reading, and when properly adjusted the indicator is sensitive to movements of half of one division. One of the instruments was calibrated at the National Physical Laboratory a little time previous to the date of these experiments.

Latometer.—For the measurement of the lateral expansion of the concrete a very simple and eventually efficient latometer was devised (*Fig.* 5). The friction referred to in the account of the preliminary experiments was entirely eliminated for the present series, and the instrument has worked very satisfactorily. A long bar, of **T** section, has a pad (subsequently replaced by a blunt steel point) pressing against the concrete and one end bent almost half way around the concrete specimen. A second bar of similar section, also with a pad pressing against the concrete diametrically opposite the first one, is connected to the first bar by a knife edge. This is held in place and the two pads pressed against the concrete by a strong spring. Thus when the concrete expands the free ends of these two bars will open. Rods are bolted at right angles to the bars at the free ends and carry blocks with **V**-grooves arranged to face each other. A spindle with one needle on one side and two on the other fits into the grooves and carries the mirror. The groove blocks are held in contact with the spindle needles by light springs. The instrument is shown in *Fig.* 5 with the calibrating bar in place of the concrete. Thus when the concrete expands, the mirror rotates and the reflected deflection of a scale is viewed through a telescope. The lever arm from the rod attachment to the pads and knife edge is 6 : 1 ; the mirror needles are $\frac{1}{2}$-in. long altogether and the optical arm usually about 80 in., thus giving a total magnification of about 2,000 from specimen to scale. This represents a strain of about 20×10^{-6} for 1 in. on the scale. The latometer has been calibrated by putting in place of the concrete a bar with a 40/50 threads per in. differential torsion head divided into hundredths round the periphery, so that one division represents $\frac{1}{20,000}$th of an inch. The calibration was found to differ by about 20 per cent. from the geometrical calculation, and this was found to be due to the bending of the various bars on account of the increased load on the spring when deflected. When designing the instrument it was thought that such a correction would be a first order small quantity. That this was not the case was proved by putting in springs of different strengths and also by replacing the spring by a definitely constant force. In the latter case the discrepancy practically vanished.

(*To be continued.*)

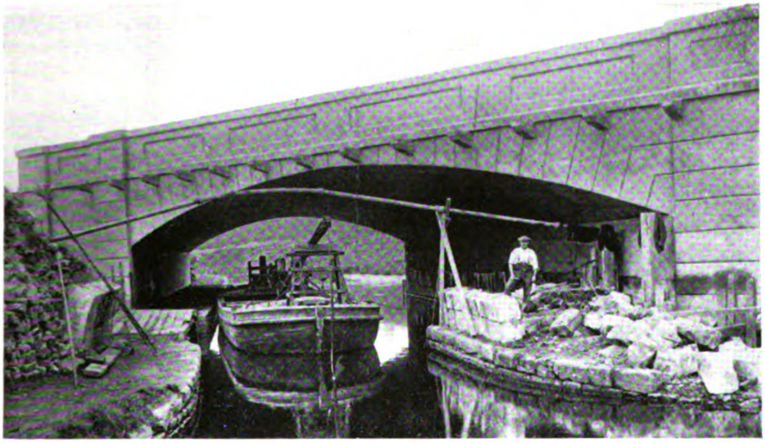
Reinforced Concrete Bridge at Barnoldswick.

A NEW bridge entirely in reinforced concrete has recently been constructed for the Barnoldswick Urban District Council in connection with the new arterial road running between Barnoldswick and Kelbrook, and carries the road over the Leeds and Liverpool Canal near Barnoldswick in the West Riding of Yorkshire. The road which has been constructed at the same time as the bridge is built on an embankment over the low ground in the neighbourhood of the canal; it has a level road surface over the bridge, rises at a slope of 1 in 30 on the Barnoldswick side, and falls at the same slope towards Kelbrook. The canal at this point runs in a line almost due north and south, and the road crossing at a very oblique angle from Barnoldswick on the west side to Kelbrook on the east side makes the bridge interesting on account of its large angle of skew of 49 deg.

The principal dimensions of the bridge are as follows: clear span on skew, 61 ft. 10 in.; clear square span, or distance between abutments, 40 ft., made up of a canal-way of 32 ft. water, plus 8 ft. towpath; clear headway above water level, 14 ft. 6 in. to the soffit of the arch crown. The rise of the arch is 6 ft., giving a headroom at springing level of 7 ft. above the towpath, which is 1 ft. 6 in. above water level. The road surface is 1 ft. 10 in. above the soffit of the arch of the crown, allowing 8 in. of filling above the top surface at this point. The width of the bridge between parapets is 70 ft., providing a 50 ft. roadway and two footpaths of 10 ft. each.

The bridge was designed as a fixed parabolic arch on its skew span, the load being the standard rolling load laid down by the Ministry of Transport for the roadway with 112 lbs. superload per sq. ft. on the footpaths. The usual stresses of 600 lbs. per sq. in. for concrete in compression and 16,000 lbs. per sq. in. for mild steel bars in tension were adopted. The slab thickness is 24 in. at the springings and 14 in. at the crown, the main reinforcement being 1⅛-in. diameter bars at 12-in. centres in both top and bottom of the slab, with additional short bars ⅞ in. diameter at 12-in. centres in both top and bottom of the slab at the springings. To allow for any short arching over the square span of 40 ft., bars ¾ in. diameter at 12-in. centres run for a short distance into the arch slab at right-angles to the abutments over the area where this might occur. Top and bottom bars are wired together throughout the whole of the slab.

The abutments, which are similar on each bank, are in reinforced concrete.



Reinforced Concrete Bridge at Barnoldswick.

The total length of each is 128 ft. 2½ in., and on account of the skew of the bridge they are only directly opposite each other for about half their length. They each consist of a base slab 15 in. thick, vertical abutment wall 12 in. thick, and ten buttresses 21 in. thick, which connect the two in a line parallel to the skew of the bridge. In addition, three buttresses are provided in each abutment to look after any straight thrust due to arching on the short span normal to the abutments.

The base slab is at a depth of 7 ft. 6 in. below water level. A small toe projecting 15 in. in front of the face of the abutment is provided to facilitate the propping for arch centering during construction. The width of the base slab is 23 ft. 9½ in., measured on the skew from the front of the toe; 10 ft. 9½ in. of this is horizontal, the remaining 13 ft. at the back sloping up to a heel-beam 7 ft. 9 in. higher, the resultant thrust being thus normal to the sloping portion of the base and the pressure within the safe limit for the stiff clay on which the structure is founded. This slab is reinforced to carry the ground reaction by spanning normally to the buttresses, the small triangle of slab at the back (left unsupported on one side owing to the skew of the buttresses) being carried on this side by the heel-beam. At the arch springing a thrust beam is provided to distribute the thrust between buttresses; this is, however, relieved to a certain extent by additional bars which project from each buttress and spread fan-shape into the arch slab. The front wall of the abutment is designed as a retaining wall reinforced horizontally between buttresses—spans of about 11 ft. 10½ in.—and has in addition some vertical steel projecting from the thrust beam to reinforce against torsion.

The end buttresses of each abutment are carried up to form wing walls and parapet piers, and these are supported by counterforts tied to the adjacent buttress in each case. The spandril walls and parapets, which are also in reinforced concrete, make the bridge a structure constructed entirely with this material. The external finish is extremely simple, the arch faces and spandrils being jointed to form voussoirs while V joints are formed in the piers above ground level. Steel angles, 4 in. by 4 in., are placed at each abutment corner as rubbing plates. The parapets, which are 4 ft. 6 in. above road level, are 6 in. thick, with panels recessed 2 in. on the outside. The parapets are surmounted by a coping, while a stringcourse projects from the base. The elevation is slightly marred by water-mains carried along the outside of the parapet on reinforced concrete brackets projecting from the spandril wall.

The removal of an old bridge of very short span which previously carried a cart-track over the canal and the building of the new bridge has allowed an increased width to the canal at this point, and this has necessitated the construction of a new towpath under the bridge on the Kelbrook side and a reinforced concrete retaining wall to this path 205 ft. long. On the Barnoldswick side reinforced concrete walls to retain the canal bank extend on each side of the abutment wall—85 ft. to the north and 40 ft. to the south. These are all cantilever walls, 9 ft. high; the slabs are 12 in. thick with a base 5 ft. 3 in. wide, 9 in. of this being toe in front of the wall.

On account of the skew of the bridge it was found that in the case of the two wing walls forming acute angles with the canal the side slope of the road embankment could not be maintained between the extremities of walls and the canal bank, and it was therefore necessary to construct extensions to these walls in order to keep within the permissible maximum slope. The extensions were constructed as buttressed retaining walls running parallel to the canal from the end pier of each wall.

Cofferdams were used in the construction of the abutments and canal walls below water-level. These were built of timber sheet piles driven by the Canal Company, whose requirements had to be observed in all matters affecting the canal and its traffic. Owing to the necessity for allowing the fullest possible canal-way during the construction of the bridge, the contractors were only permitted to construct one abutment at a time; thus the abutment and canal walls had to be completed on the Barnoldswick side, which was constructed first, the sheet piles then being drawn and driven on the Kelbrook side before work could be started there. This caused a certain amount of delay in the construction.

Throughout the work the centering, shoring and timbering were erected so as not to interfere with the navigation of boats in the canal, a clear headway of 9 ft. 6 in. being required for this purpose between top water-level and the underside of the centering for the arch.

The concrete used was of very good quality, composed of: Shap granite chippings graded ¼ in. to ¾ in., 27 cubic ft.; sand, 13½ cubic ft.; Portland cement 5½ cwt.; all gauged in boxes and machine mixed. As a waterproof course against percolation, two layers of asphalte, ¾ in. total thickness, were laid over the whole of the upper surface of the arch slab, the inside of the spandrils up to the base of the parapet, and the rear side of the abutments to a depth of 6 ft.

The design and construction of the bridge were carried out under the supervision of the consulting engineer, Mr. W. Matthews Jones, the reinforcements being supplied by the British Reinforced Concrete Engineering Co., Ltd., Manchester. The contractors for the work were Messrs. J. Wimpenny & Co., of Linthwaite, near Huddersfield.

The Behaviour of Reinforced Concrete under Tension.

THE question of the relative elastic extensions of plain and of reinforced concrete is still one on which engineers are not agreed completely. The experiments of M. Considère (*Comptes rendus de l'Académie de Sciences*, 1898 and 1905) brought to light the noteworthy fact that reinforced concrete undergoes a larger extension before breaking when submitted to tensile stress than plain concrete. This fact has been confirmed by the later tests of M.M. Mesnager and Mercier, but the exactness of the results has been questioned by Bach.

A further contribution to the solution of this problem is given in *Il Cemento Armato* by M. Greco, who carried out tests on 70 mm. by 70 mm. square specimens, 310 mm. in length, exclusive of two 70 mm. long heads, which are gripped by the testing machine. Each reinforced test-piece contained nine bars of approximately 5 mm. diameter. Copper moulds were used for casting the test pieces. The cement employed gave 309 lbs. per sq. in. in tension and 4,842 lbs. per sq. in. in compression on standard mortar specimens. The sand used gave the following analysis when shaken on a mechanical sifter for six minutes:

Residue on a sieve with
holes 2 mm. in diameter = 0·092 kg.
,, 1·5 ,, ,, = 0·234
,, 1·0 ,, ,, = 0·205
,, 0·5 ,, ,, = 0·151
Fine dust = 0·318

Total . . . . 1·000 kg.

Marine gravel passing a sieve with 10 mm. holes and retained by 5 mm. holes was employed.

The mix was 1 : 1·8 : 3·3 by weight of dry materials, and a standard hammer apparatus was employed in filling the moulds. Extensions were measured along a central length of 150 mm.

An extract from the results is given below:

Load (Kg.).	Age 162–164 days.	
	Plain concrete.	Reinforced Concrete.
	Extension in mm. × 10^{-3}	
200	3·9	4·2
300	6·0	7·9
400	7·9	11·0
500	10·0	15·0
600	11·9	22·3
700	14·6	25·7
800	17·6	31·2
900	21·00	36·4
1000		42·9
1100		49·4
1200		55·7
1300		62·3
1400		69·6
1500		79·9
1600		83·6
1700		90·7

The following table gives the ratios of the extensions for plain and reinforced test-specimens:

Reference number.	Max. load.	Max. extension in mm. per metre.	Ratio of extensions.
	Kg.		
H Plain concrete	900	0·070	$\frac{\cdot 302}{\cdot 070} = 4\cdot 3$
G Reinforced	1700	0·302	
L Plain	800	0·062	$\frac{\cdot 233}{\cdot 062} = 3\cdot 9$
E Reinforced	1600	0·233	
B Plain	1300	0·072	$\frac{\cdot 251}{\cdot 072} = 3\cdot 5$
A Reinforced	2000	0·251	
D Plain	900	0·066	$\frac{\cdot 258}{\cdot 066} = 3\cdot 9$
C Reinforced	1900	0·258	

Age of specimens: H and G, 162–164 days; L and E, 182–183 days; B, A, D, and C, 236–238 days.

From the results given by specimens H and G the unit extensions are respectively, for a load of 900 kg.,

$$\frac{0\cdot 021}{300} = 0\cdot 00007 \text{ and } \frac{0\cdot 0364}{300} = 0\cdot 000121.$$

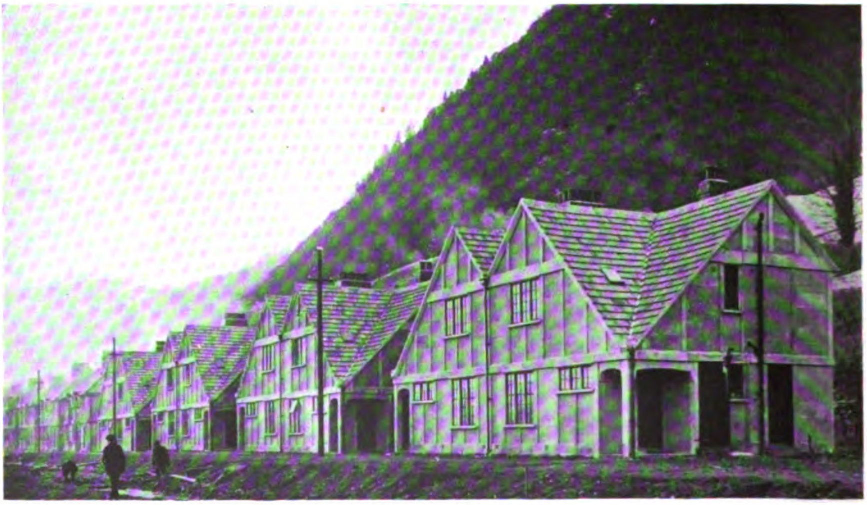
In specimen H the stress in the concrete is $f = \frac{900}{A} = \frac{900}{49} = 18\cdot 3$ kg.cm² and in G it is $f = \frac{900}{49 + (6 \times 1\cdot 91)} = 14\cdot 9$ kg.cm².

Therefore a tensile stress of 18·3 kg.cm² produces a unit elongation of 0·00007 in plain concrete and a stress of 14·9 kg.cm² produces a unit elongation of 0·000121 in reinforced concrete. In other words, under a stress of 14·9 kg.cm² the reinforced concrete undergoes an extension nearly double that suffered by the plain concrete.—W.S.G.

New Method of House Construction.

THE concrete cottages illustrated have been built recently on a system invented by Mr. Hamish Cross, of the Abdon Clee Stone Quarry Co., Ltd., of Bridgnorth. As will be seen, the system is of the pier-and-panel type, all the units being pre-cast.

The lower columns are 9 in. by 6 in. extreme dimensions, reinforced with four steel bars connected by stirrups of mild



"Hamish Cross" Houses at Dolgarrog.

"Hamish Cross" Houses at Neasden.

steel. These lower columns finish at the stringcourse, the reinforcement projecting into it and being connected to the reinforcement of the stringcourse.

A pre-cast hollow stringcourse forms a trough all around the building, with reinforcing bars throughout its length. The bars of the stringcourse are connected to the reinforcement of the bottom columns, and also run through the bottom of the top columns. When the bottom and top columns are in position the hollow string is filled with concrete, tying and uniting the whole building.

The upper columns are 6 in. by 6 in. (extreme dimensions), having a knee which fits into the string. Through this knee are two slotted holes through which the stringcourse reinforcement passes, and the whole is concreted together.

Directly under the wallplate sufficient space is left in the column heads and between the inner and outer slabs for a line of reinforcement, which is concreted *in situ*, again tying the whole building.

The columns are placed at such intervals as may be necessary.

A cavity wall is formed, the slabs forming the outer panels between the columns are reinforced and made of gravel concrete, while the slabs on the inner face are made of a mixture of breeze and gravel. Mr. C. W. Clark, of the Metropolitan Railway Company, is the architect of the houses illustrated.

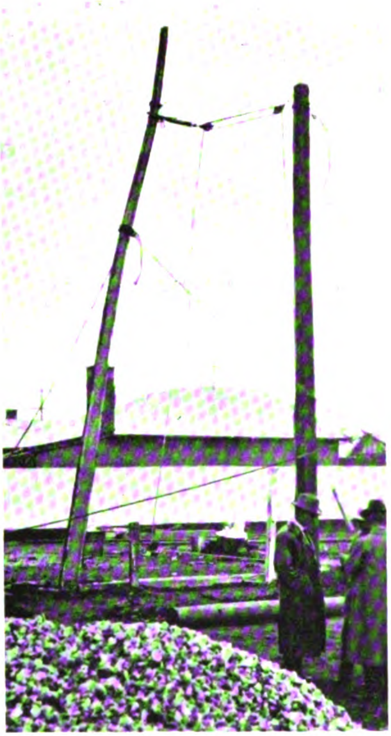
Reinforced Concrete Stairs.

An article by A. Habel in "Beton und Eisen" treats the subject of stair construction from the point of view of the relative economy of the three main types in use, namely (1) the simple slab spanning from landing to landing, (2) stairs with stringers, and (3) stairs cantilevered from a wall at one side.

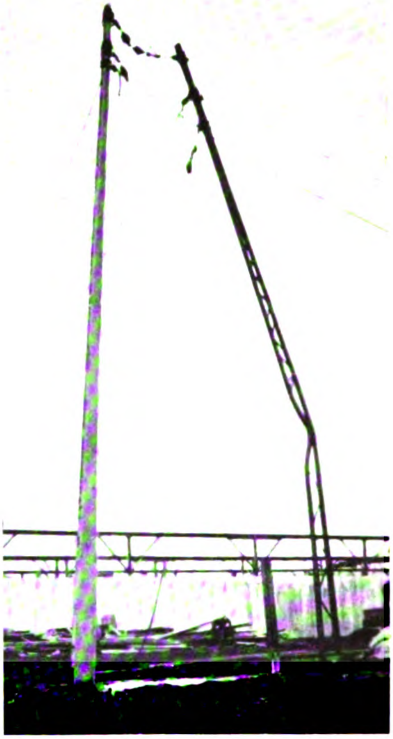
In order to obtain his results the author has assumed a super-load of 100 lbs. per sq. ft., a 6½-in. riser, and values of f_c and f_s. These latter two are 500 lbs. sq. in. and 14,000 lbs. sq. in. for types (1) and (2), and are reduced to 430 and 11,400 respectively for type (3).

The general conclusions at which the author arrives are that type (1) is the least economic, type (3) is the most economic when the flights are very long, even for wide steps, and is the cheapest of all when the steps are very narrow. For wide steps with the usual lengths of flights found in practice type (2) is most advantageously used.

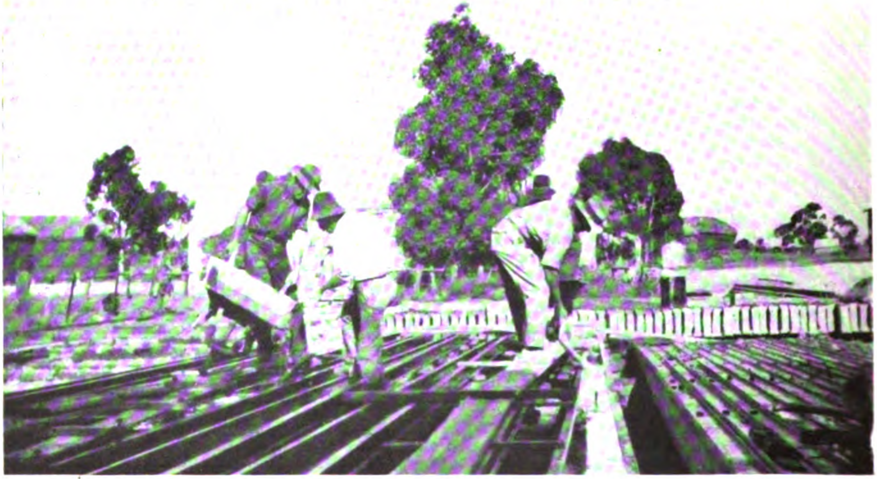
Tables are given which allow one to judge of the comparative economy of the various types in different conditions.—W.S.G.



Test on Steel-and-Concrete Pole: Permanent Set of 4 ft. 6 in. at top after Pull of 1,500 lbs.



Test between Steel-and-Concrete Pole and Fabricated Steel Pole; the latter failed at 1,300 lbs., while the former had only a slight Permanent Set.



Manufacture of Steel-and-Concrete Poles.

Steel-and-Concrete Transmission Poles. (*See p.* 323.)

The "Stobie" Steel-and-Concrete Pole.

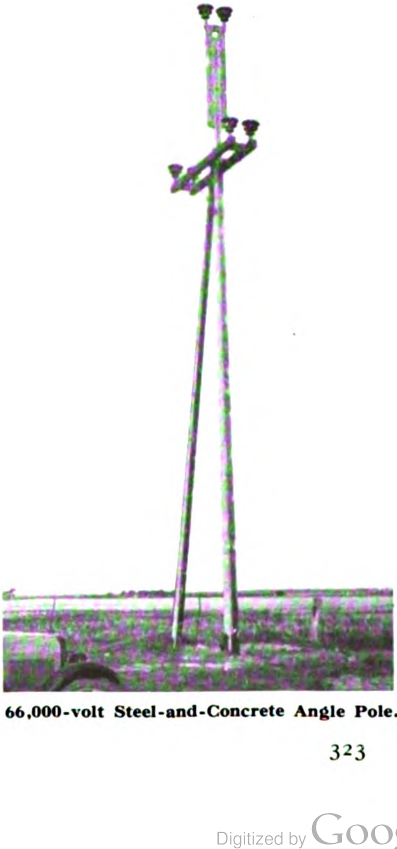
THE "Stobie" steel-and-concrete pole for carrying overhead electric lines, which is the subject of recent British and other patents, is an Australian invention. In that country it has been used with satisfactory results, and already about 150 miles of high-pressure overhead transmission lines with "Stobie" poles have been constructed.

The essential features of its design are the use of two light standard rolled-steel joists or channel sections, forming the main outside tension and compression members. These are held at their correct distances apart, and with their proper taper from the base to the top of the pole, by bolts passing through the webs of the sections at intervals. The whole triangular space between these sections, as they lie on the ground with their top and bottom moulds, is then filled with a stiff concrete mixture. The concrete filling, when set, acts as a continuous web, with the embedded bolts taking a portion of the shear stresses. This filling also gives to the completed pole the necessary rigidity and resistance to torsion which may arise from an unbalanced pull. The bolt holes for attaching the insulator cross-arms are cast in the concrete at the time of pouring. The poles are usually erected complete with cross-arms, insulators, etc.

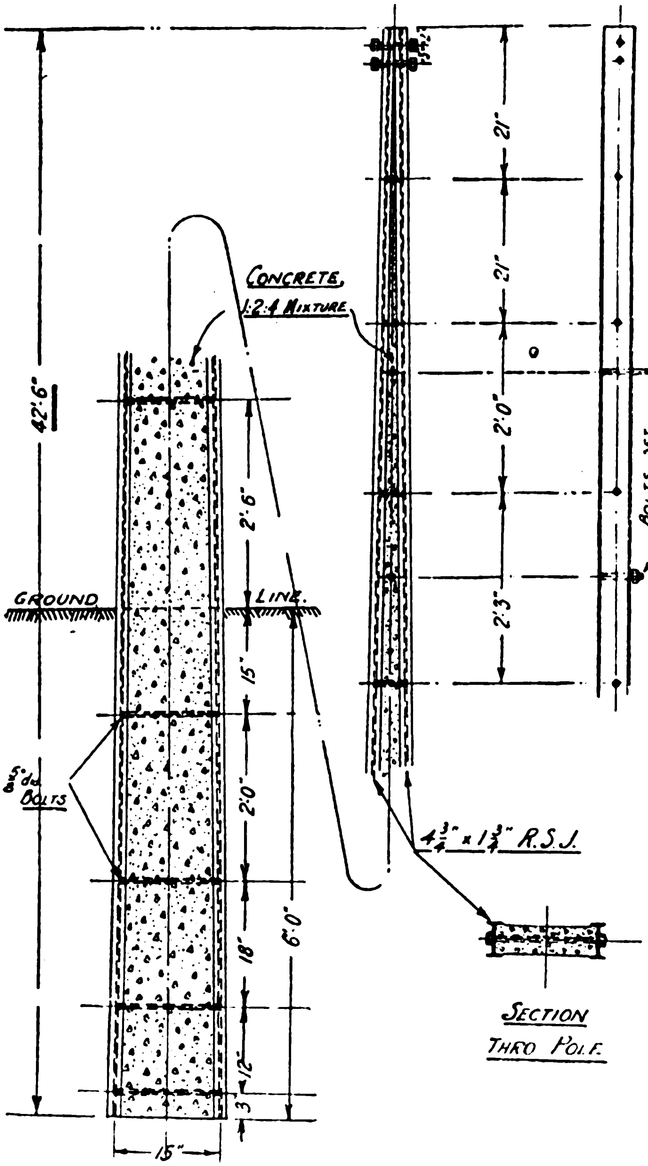
The process of manufacture calls for no special machinery nor skilled labour. As the majority of the poles so far used in Australia have been for transmission lines remote from railway facilities, the materials for their construction were transported to a number of depôts on the route of the lines. Here the poles were cast and the concrete allowed to season for from 14 to 21 days. The completed structures were then despatched to the points on the line as required, an arrangement which necessitated the minimum of transport for the poles. Although many were carried 20 miles on timber jinkers over rough Australian tracks not a single pole was damaged from the severe handling and jolting it received.

The particular claims made for the "Stobie" poles are that by correct section and disposition of the members to withstand the stresses usual in overhead lines they are, for equal strength, no heavier than corresponding hardwood poles; while their cost, taking into consideration a longer life, is substantially less than that of wooden poles and compares favourably with fabricated steel structures. As already mentioned, they are particularly suited for long distance transport. In countries where the transport of heavy weights is either difficult or expensive, the pole can be manufactured with equal facilities on the site of the transmission line itself.

The "Stobie" pole has been built in 30-ft. and 36-ft. lengths for local low-voltage distribution purposes, and in 42-feet and 50-ft. lengths for 33,000-volt double-circuit transmission lines; but the design is one which shows considerable advantage over wooden poles and fabricated steel structures for lengths much in excess of these.



66,000-volt Steel-and-Concrete Angle Pole.



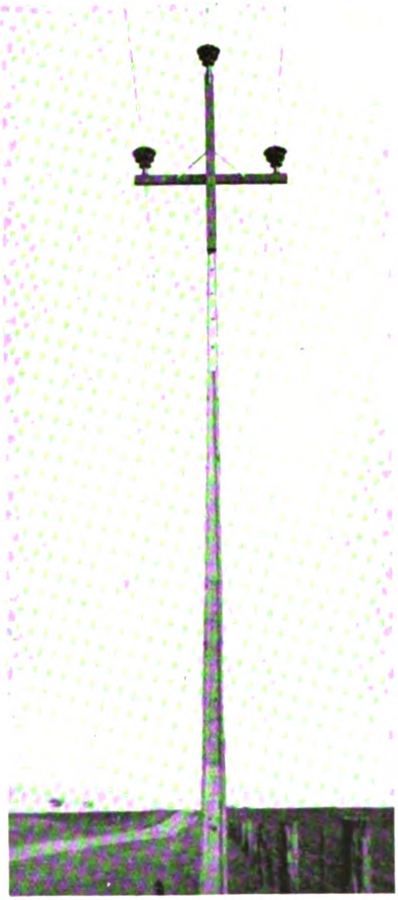
Steel-and-Concrete Transmission Poles.

Before the "Stobie" pole was adopted as a standard for its transmission lines by one of the operating companies in Australia a series of tests to destruction in comparison with wood and steel fabricated structures was carried out. In one of these tests a steel-and-concrete pole was tested against a steel fabricated pole, both being designed for the same side pull. In this test, while both poles showed similar deflections, viz. 4-in., at the designed pull of 500 lbs., the fabricated steel pole completely collapsed at about 1,300 lbs., while the "Stobie" pole only showed a heavy permanent set without fracture. Other tests showed that the "Stobie" pole, as designed, has a factor of safety of 3 for loads at right-angles to the line which is considered satisfactory for such structures; while its strength in the direction of the line complies with regulation requirements and is ample for ordinary contingencies.

In a further test a 30-ft. pole made to standard design, using 4 in. by 1¾ in. rolled steel joists, was twisted at the top with a pull of 13,000 in.-lbs. through an angle of 50 deg. After release the pole came back to its normal position with only a slightly appreciable "set." The same pole was afterwards subjected to a bending test in the direction of the line, and withstood a pull of 640 lbs. at 1 ft. from the top before failure. This size pole had been previously tested to have an approximate ultimate strength of 1,500 lbs. across the line; its strength in the direction of the line is therefore rather more than 40 per cent. of that across the line.

The question of possible corrosion of the steel members at the ground-line is receiving attention, and it is considered that in dry climates, such as Australia, little more protection than the coat of paint which the pole receives on erection will be necessary. For moister conditions, a coat of bitumastic enamel applied hot to the base, either with or without the usual weathered concrete footing, carried 12 in. above and below ground, will afford sufficient protection to ensure the pole a very long life.

It is anticipated that following the installation of the "Stobie" pole in Australia, arrangements will shortly be made for its manufacture in other countries.



66,000-volt Steel-and-Concrete Line Pole.

Back Numbers Wanted.—A subscriber wishes to secure copies of "Concrete and Constructional Engineering" for February and October, 1923. Replies to Box 1296, CONCRETE AND CONSTRUCTIONAL ENGINEERING 20 Dartmouth Street, Westminster, S.W.1.

Curing Concrete in a Semi-Arid Climate.

A REPORT on "Methods of Curing Concrete in a Semi-Arid Climate," by Messrs. Harrison F. Gonnerman and C. L. McKesson, has just been published as Bulletin 15 of the Structural Materials Research Laboratory, Lewis Institute, Chicago.

This investigation was conducted at Sacramento, Calif., where the climatic conditions were quite unfavourable for the proper curing of unprotected concrete, but are typical of those encountered in semi-arid regions.

The experiments were carried out on 7 in. by 10 in. by 38 in. Portland cement concrete beams made out of doors and cured in the open. Curing methods included :

(1) Covering of wet earth.

(2) Covering of asphaltic paper.

(3) Surface application of flake calcium chloride.

(4) Surface application of sodium silicate.

(5) Air exposure.

A total of 518 beams were tested in cross-breaking with the cured surface in tension at ages of 3 to 90 days. The hardness of the cured surfaces of the beams was measured by a ball-indentation test. Compression tests were made on one hundred and seventy-five 6 in. by 12 in. cylinders and prisms in order to secure a measure of the quality of the concrete in a standard test.

In comparing the relative efficiency of the different curing methods, the strength of the concrete cured with wet earth at 7 and 14 days (which showed practically identical results) was taken as the standard. The "strength-ratios" for the different methods of curing were based on the following values of modulus of rupture of 1 : 2·2 : 3 concrete : 7d., 445 ; 14d., 470 ; 28d., 535 ; 90d., 600 lbs. per sq. in. (The 28-day compressive strength was 4,000 lbs. per sq. in.)

The principal conclusions from the tests are :

(1) A curing method is efficient which maintains the moisture content of the concrete, during the early stages of hydration, about equal to the original mixing water. Wet-earth curing gave the best results ; this method apparently supplied moisture in sufficient quantity to replace losses due to evaporation and to absorption by the subgrade. Curing methods which permitted high evaporation losses gave concrete of low strength.

(2) The tests showed that concrete cured under wet earth for 7 or 14 days was only slightly stronger than when cured under wet earth for 3 days. In view of this and of the small rate of increase in strength after the fourteenth day it may be concluded that with temperature no lower than prevailed in these tests (70 deg. F.) concrete pavements cured by covering with wet burlap for 16 to 24 hours and then with earth kept wet for 7 days may safely be opened to traffic in 14 days.

(3) Curing with a surface application of flake calcium chloride, 2½ lbs. per sq. yd., gave strength-ratios of from 88 per cent. at 7 days to 83 per cent. at 90 days ; with less than this amount, and with 3 and 5 lbs., there was a slight reduction in strength. When the calcium chloride was washed off after 3 hours the strengths were reduced perceptibly ; washing off calcium chloride after 1 day gave essentially the same strengths as when left on the surface. Surface hardness for calcium chloride-cured beams was considerably less than for beams cured with wet earth or with asphaltic paper.

(4) For beams moulded and cured in concrete forms using calcium chloride, 2½ lbs. per sq. yd., the strength-ratios ranged from 100 per cent. at 14 days to 89 per cent. at 90 days. The strengths in this case were about 12 per cent. higher than for beams moulded in wood forms and cured with a similar amount of calcium chloride.

(5) Asphaltic paper curing gave average strength-ratios ranging from 92 per cent. at 7 days to 78 per cent. at 90 days ; surface hardness was almost as high as for wet-earth curing.

(6) Both air curing and sodium silicate curing showed low strength and surface hardness. The strength-ratios for these methods of curing ranged from 77 per cent. at 7 days to 74 per cent. at 90 days.

(7) Indentation loads used in measuring surface hardness averaged 21 times the modulus of rupture ; the greatest surface hardness was found for concrete of highest flexural strength. This method of test showed that calcium chloride, sodium silicate, and air curing produced a more friable surface than wet-earth or paper curing.

Influence of Contraction and Expansion on Rigid Frames.

CONCRETE which is not kept under water undergoes a contraction during the hardening period of about 4×10^{-4} per unit of length. This contraction, or an expansion due to temperature, will produce stresses in rigid frames of reinforced concrete. In *Le Constructeur de Ciment Armé*, M. F. Grassi has shown how these stresses may be calculated, and the following article is based on his contribution to that periodical.

In general the footings will not be perfectly fixed and some rotation of the lower ends of the columns will take place. These angular movements will depend on the resistance of the ground. The amount of settlement of the ground is proportional to the pressure on it, that is, $p = KZ$ (see *Fig.* 1) where Z = amount of settlement and K is found by experiment. Let f and g denote the lengths of the sides of the footing and Z_1 and Z_2 the settlements at each edge, then the angle $\theta_0 = \frac{Z_1 - Z_2}{f}$, and if p_0 = the mean pressure, $Z_1 = \frac{p_0}{K}\left(1 + \frac{6d}{f}\right)$ and $Z_2 = \frac{p_0}{K}\left(1 - \frac{6d}{f}\right)$.

Let $AB = d$ = distance between centre of pressure and centre of footing and R = ground reaction, then

$$\theta_0 = \frac{p_0 \times 12d}{Kf^2} \quad \text{or,} \quad d = \frac{Kf^2}{12p_0}\theta_0$$

and

$$M_0 = Rxd = p_0fg \times \frac{Kf^2}{12p_0}\theta_0 = \frac{Kf^3g}{12}\theta_0.$$

In other words the angular rotation at the column foot is $\theta_0 = \frac{12M_0}{Kf^3g}$.

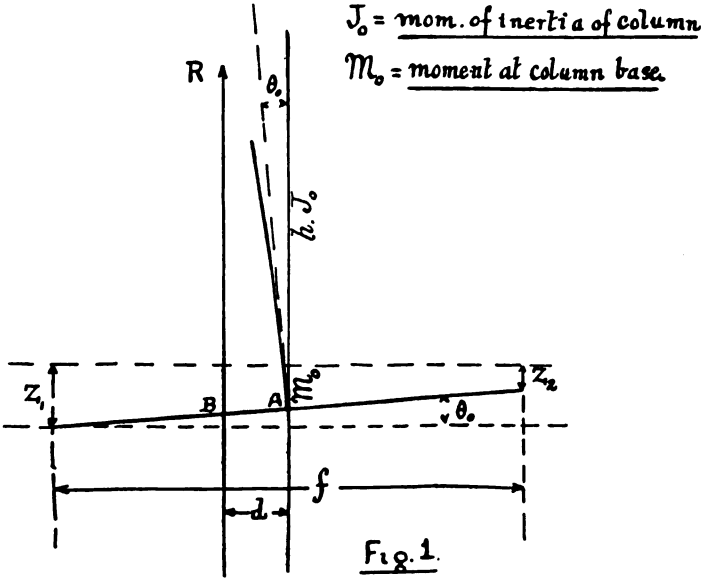

J_0 = mom. of inertia of column
M_0 = moment at column base
R
θ_0
$h.J_0$
M_0
Z_1
Z_2
B
A
θ_0
f
d

Fig. 1.

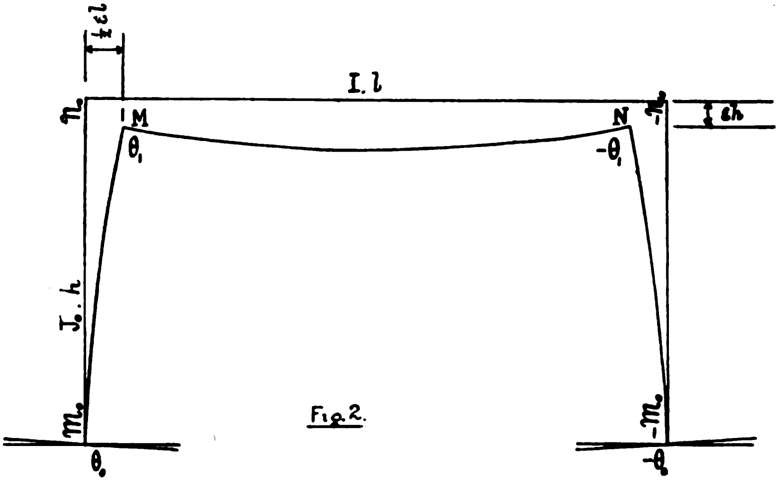


Fig. 2.

In *Fig.* 2, for the beam, we have

$$-N_0 = \frac{4EI_1}{l_1}\theta_1 - \frac{2EI_1}{l}\theta_1 = \frac{2EI_1}{l}\theta_1 \text{ by Möhr's slope-deflection equation;}$$

therefore $\theta_1 = -\dfrac{l}{2EI_1}N_0$, where N_0 is the moment at the upper end of the column.

Also, for the left-hand column,

$$\left.\begin{aligned} -\frac{hel}{2} - h^2\theta_0 &= \frac{h^3}{3EJ_0}M_0 + \frac{h^3}{6EJ_0}N_0 \\ \text{and} \qquad \frac{hel}{2} + h^2\theta_1 &= \frac{h^3}{6EJ_0}M_0 + \frac{h^3}{3EJ_0}N_0 \end{aligned}\right\} \cdot (A)$$

In the example (*Fig.* 2) $h = 8$ m., $l = 15$ m., $J_0 = 0{\cdot}01$, $I = 0{\cdot}06$, $f = g = 1{\cdot}50$ m., $E = -4 \times 10^{-4}$, ${}^4K = 10^4$ (corresponding to a settlement of 1 mm. per kg. of pressure per sq. cm.,) and $E = 2 \times 10^6$ tonnes/métre². Here

$$\frac{h^3}{6EJ_0} = \frac{8 \times 8 \times 8}{6 \times 2 \times 10^6 \times 0{\cdot}01} = 0{\cdot}004266$$

Also, $\qquad \theta_0 = 0{\cdot}000237\, M_0$

and $\qquad \theta_1 = -\, 0{\cdot}0000625\, N_0.$

Substituting these values in equations (A), above, we get

$$M_0 = -\, 1{\cdot}446 \text{ tonnes-métre,}$$

$$N_0 = \text{M} = \text{N} = 2{,}408 \text{ tonnes-métre,}$$

$$\text{(in English units } N_0 = \text{M} = \text{N} = 208{,}000 \text{ in. lbs.),}$$

as the bending moment caused by the contraction of the concrete in hardening.

It is found that in a construction of one span with several floors the most severe moments are produced at the intersections of the bottom beams with the tops of the lowest columns, and that the values of the moments rapidly decrease at the upper intersections and are negligible above the third floor.—W. S. G.

The Simple Theory of Bending.

Modified for the Case where the Tensile and Compressive Moduli are unequal.

By F. E. RELTON, B.A., B.Sc.

Building Research Station.

In the course of a report (published in *Concrete and Constructional Engineering* for November 1923) of an investigation on spun concrete pipes carried out at the Building Research Station, it was pointed out that the tension and compression moduli were unequal. It is well known that many other materials, e.g. cast iron, possess this property in some degree,* and it accordingly becomes of interest to inquire what one is to take as the modulus in applying the ordinary beam theory, i.e. what formulæ correspond to $M/I=E/R=f/y$ in these circumstances. Concrete, of course, does not yield a linear stress-strain relation, but in general one can at least achieve a first approximation on the following assumptions :—

(i) The bending is "simple," i.e. pure couples without shear,

(ii) Plane transverse sections remain plane and normal,

(iii) Young's modulus for tension is different from that for compression, but

(iv) The material obeys Hooke's law, whether in tension or compression.

We proceed first to discuss the matter in general terms for any shape of section. In *Fig.* 1 let NX be the neutral axis, dividing the cross-sectional area into two parts, upper and lower. Let

A_1A_2A	denote	the upper, lower and whole area,
C_1C_2C	,,	their respective centres of gravity,
c_1c_2c	,,	the distances of these C's from NX,
I_1I_2I	,,	the moment of inertia of each area about an axis parallel to NX through its centre of gravity.
E_1E_2	,,	Young's modulus for the upper and lower areas,
R	,,	the radius of curvature of the bent beam,
M	,,	the bending moment.

We have the obvious relation

$$A_1+A_2=A \quad . \quad . \quad . \quad . \quad (1)$$

By moments about the neutral axis we have

$$A_2c_2-A_1c_1=Ac \quad . \quad . \quad . \quad (2)$$

Consideration of the moments of inertia about NX yields

$$(I_1+A_1c_1^2)+(I_2+A_2c_2^2)=(I+Ac^2) \quad . \quad (3)$$

In order to produce a couple the total tensile and compressive forces must be equal and opposite, whence

$$E_1A_1c_1=E_2A_2c_2 \quad . \quad . \quad . \quad (4)$$

and by analogy with the ordinary theory we have obviously

$$E_1(I_1+A_1c_1^2)+E_2(I_2+A_2c_2^2)=RM \quad . \quad (5)$$

When the shape of the cross section is known, A, C and I can be determined absolutely and A_1, c_1 and I_1 can be determined in terms of c. Equations (1), (2), and (3) in succession then determine A_2, c_2 and I_2 in terms of c, so that (4) then determines c absolutely and (5) can then be simplified.

We note that if $E_1>E_2$, then $A_1c_1<A_2c_2$ from (4), whence c is positive from (2) and the figure is as drawn, i.e. mathematics proves what common sense indicates, that the neutral axis moves from the centre of gravity towards the part with the greater modulus.

At the same time, if f denote the stress at a distance y from the neutral axis, we have $f\propto yE$, so that connecting A_1 and A_2 we have

$$f_1/f_2=y_1E_1/y_2E_2 \quad . \quad . \quad . \quad (6)$$

and consideration of the moment of resistance yields

$$f_1I_1/y_1+f_2I_2/y_2=M \quad . \quad . \quad . \quad (7)$$

As soon as the shift of the neutral axis has been calculated the values of y_1 and y_2 become known, and the last two equations serve to determine f_1 and f_2, so that the problem is then completely solved.

Although the foregoing is satisfactory inasmuch as it treats the problem in its most general form, it does not necessarily give the method best suited to use. As

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[* See, for example, Johnson's "Materials of Construction," 5th Edition, p. 617; see also Dalby's "Strength and Structure of Steel and Other Metals," p. 144.]

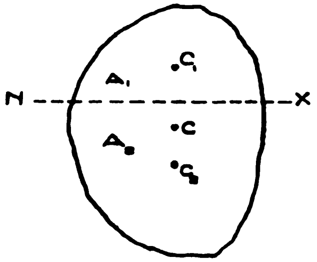


Fig. 1.

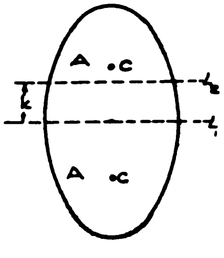


Fig. 2.

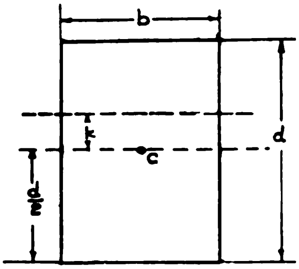


Fig. 3.

a matter of fact, if the cross-sectional area has a horizontal axis of symmetry, it is preferable to work about the axis of symmetry rather than about the neutral axis. In this case (*Fig.* 2) let

L_1 be the axis of symmetry
L_2 the neutral axis
k the distance between L_1 and L_2
A half area of cross-section
a area between L_1 and L_2
C centre of gravity of half area
c distance of C from L_1
c_1 distance of c.g. of a from L_1
I moment of inertia of A about L_1
I_1 moment of inertia of "a" about L_1

Corresponding to equation (4) we now have

$$E_1[A(c-k)+a(k-c_1)]=E_2[A(c+k)+a(k-c_1)] \quad (4a)$$

By putting $(E_1+E_2)=s(E_1-E_2)$ we can re-write the last equation as

$$A/a=(k-c_1)/(ks-c) \quad . \quad . \quad . \quad (4b)$$

When the shape of the figure is given, A and c are known, c_1 and "a" can be found in terms of k, and the above equation then determines the value of k.

Coming now to the moment of resistance, we have that the moment of inertia of the upper A about L_2 is $I-Ac^2+A(c-k)^2$ or $I-Ak(2c-k)$, the corresponding quantity for "a" being $I_1-ak(2c_1-k)$. The difference of these, which for brevity we may denote by (U), represents the moment of inertia about L_2 of the part above L_2, its value being $(I-I_1)+k^2(A-a)-2k(Ac-ac_1)$. The corresponding quantity for the part below L_2, which we will denote by (V), has the value $(I+I_1)+k^2(A+a)+2k(Ac-ac_1)$, so that equation (5) can be written

$$RM=E_1(U)+E_2(V) \quad . \quad . \quad . \quad (5a)$$

As an example of the application of the foregoing analysis we consider the case of a rectangular beam of breadth b and depth d. We have immediately from *Fig.* 3 the relations

$$A=bd/2 \qquad a=bk$$
$$c=d/4 \qquad c_1=k/2$$
$$I=bd^3/24 \qquad I_1=bk^3/3$$

By direct substitution, equation (4b) becomes on reduction

$$4k^2=4kds-d^2$$

As k is necessarily $< d/2$ we must choose the smaller root,

$$\therefore 2k=d[s-\sqrt{(s^2-1)}]=d(\sqrt{E_1}-\sqrt{E_2})/(\sqrt{E_1}+\sqrt{E_2})$$

If we write $E_1/E_2=g^2$, the last relation can be written as $2k=d(g-1)/(g+1)$. Usually the excess of g above unity will be small, so if we further write $E_1/E_2=g^2=1+t$, we have as an approximation $g=1+t/2$ and our relation becomes, after some slight reduction, $k=dt/8$. For example, if E_1 and E_2 differ by 10 per cent. the neutral axis is displaced from the middle by an eightieth of the depth.

Reverting for a moment to equation (6), we have $E_1/E_2=11/10$ and $y_1/y_2=39/41$, so that $f_1/f_2=11.39/10.41=1{\cdot}046$ and the stiffer side has the greater skin stress by about 4½ per cent.

The corresponding reduction for equation (5a) leads to some straightforward but decidedly lengthy algebra, eventuating in the result $RM=8IE_1/(g+1)^2$. Now $1/(g+1)=(1/2-k/d)$, and as $k/d=t/8$ we get the equivalent approximation $RM=IE_1(2-t)$. Since $E_1/E_2=1+t$, we have $(E_1+E_2)/E_1=(2+t)/(1+t)=(2-t)$, so that $RM=EI$, where $E=E_1+E_2$. Remembering that I relates to only half the area, we see that mathematics substantiates what common sense indicates, viz. that a valid approximation is obtained by taking as the equivalent modulus the arithmetic mean of the two known moduli.

Two other obvious applications are to the circular and annular cross-sections. The procedure involves little more than the computation of certain segmental areas and moments of inertia, but in their general form the resulting equations are distinctly cumbersome; indeed, an exact solution is impossible owing to the transcendental nature of the equations involved. Nevertheless, if we make the legitimate assumption that the shift of the neutral axis is but a small fraction of the radius, the relations become rational and integral on using approximate expansions for such terms as $\sin^{-1}x$ and $\sqrt{(1-x^2)}$ where x is small.

It would be tedious to reproduce here all the algebra involved, and we content ourselves with remarking that for the circular section the result is $k/r = 4/3\pi s$ where s has already been defined by the relation $(E_1+E_2) = s(E_1-E_2)$. Taking as an illustration our previous example where the moduli differ by 10 per cent., we see that s is 21 and the neutral axis shifts by about 1/50 of the radius. As one would expect, this is less than in the case of the rectangular section. On the other hand, the ratio of the skin stresses is now $f_1/f_2 = 11.49/10.51 = 1{\cdot}057$, so that they differ by some 5·7 per cent., which is greater than before. This may at first sight appear anomalous, but a little reflection shows that it must be so. If it were conceivable that the neutral axis did not move, the skin stresses would be in the same ratio as the moduli, i.e. they would differ by 10 per cent. In any section where the shift of the neutral axis is slight, this 11/10 ratio will be only slightly affected. Such a section as an **I**-section would tend to keep the skin stresses equal.

In the case of an annular section of internal and external radii R and r, we find

$$k = 4(R^3 - r^3)/(R^2 - r^2)3\pi s$$

When r approaches zero this reduces to our previous result; but as r approaches R the result must be used with considerable caution. Eventually the approximation becomes invalid owing to the distortion that occurs when thin-walled cylinders are bent.

It may be remarked that, as in the case of the rectangular beam, a legitimate first approximation for both the circular and annular sections is to take the modulus as the average of the two known moduli.

Certain experimenters have found that the modulus as determined by deflection lies outside, instead of between the tensile and compressive moduli. The explanation of this anomaly (if it really exists) may be temporarily left to the curious; it probably lies in the illicit assumption that plane sections remain plane.

DESIGN OF FORMWORK.

With our last issue we completed a series of extracts from Mr. A. E. Wynn's book on "Design of Formwork for Reinforced Concrete Construction." Other Chapters of this work deal with formwork for different types of bridges, "flat-slab" construction, the various types of climbing and sliding forms, forms for dams and retaining walls, etc., and the various patented devices used in formwork, while other chapters deal with the layout of formwork and the design of forms in the office. As will be seen, the work covers every aspect of the design, erection, stripping, and costing of shuttering for every class of concrete work, the whole of which is dealt with in a very comprehensive manner. The extracts which have been given in this journal, together with the new chapters, will be published in book form in the Autumn by Concrete Publications, Limited. This is the only volume published in the English language dealing exhaustively with the subject of formwork for reinforced concrete, and embodies the very wide experience the author has gained with the most up-to-date and economical methods both in this country and in America.

Design of Floors and Foundations.

NEW SYSTEM USED AT LEEDS SEWAGE DISPOSAL WORKS.

A NEW system of reinforced concrete by which, it is stated, a saving of over £100,000 was effected in the construction of the new Leeds sewage disposal works, was described by Mr. D. Davidson, F.R.S.A., at a meeting of the Yorkshire Branch of the Institution of Structural Engineers.

The system, he said, had a very economical application in the case of wide-span floors for factories, warehouses, hospitals, and similar structures. For heavy floor foundations for engineering and architectural works, to be carried by poor-bearing strata of a semi-liquid and plastic nature, or of the nature of running sand, the system was markedly efficient and economical. When to these conditions of construction and foundation strata was added the problem of alternations of upward and downward pressure, actual experience had proved that an economy of at least 50 per cent. was effected by the application of the new system. Under the conditions mentioned, the application of the system to the floors and foundations of the new sewage settlement tanks at the low-level sewage disposal works of the Leeds Corporation showed that the saving on ordinary methods of construction amounted to 53½ per cent. The most economical of the ordinary methods of construction gave a cost of £215,000, whereas the new system gave a cost of less than £100,000, thus representing a saving of over £115,000. The various alternative designs were submitted by the Sewage Engineer, Mr. George A. Hart, M.Inst.C.E., to Mr. Basil Mott, M.Inst.C.E., for expert criticism. Mr. Mott, after prolonged and careful consideration and investigation, reported in favour of the new system on grounds of both efficiency and economy.

In the design of a raft foundation system to be carried on semi-liquid river silt, mobile plastic clay, or running sand, either the foundation area must be completely enclosed within a casing of sheet piling, or group piling over the whole area must be adopted. If the raft foundation in such cases were built merely to float, without being encased, inequalities in distribution of loading or inequalities in bearing resistance were liable to tilt the raft or to break the back of the raft. Once a movement or settlement due to one or other of these causes had taken place it was a very difficult and costly matter to make good the damage done.

In the case of the Leeds low-level sewage disposal works, the difficulties were accentuated by the fact that some of the older works, which had to be retained, were "floating" on river silt, varying in depth up to 10 ft. and over, and that the construction of the foundations of the new works, if carried out by ordinary methods at a considerably lower level than the foundations of the old works, would cause flow of silt from under the old works. Subsidence of the old works had already taken place—varying in extent from 3 in. to 12 in., depending upon the depth of silt. The maximum downward pressure under which this subsidence took place did not exceed 7 cwt. per sq. ft., which was the bearing resistance of the silt for incipient failure. The maximum resultant downward pressure for the new sewage tanks, however, was 8 cwt. per sq. ft., ground conditions and the necessary depth for future tankage on the available site requiring the new tanks to be of greater depth and higher top-water level than the old tanks.

Owing to the conditions imposed by the site, the new tanks also had to be designed for alternations of downward and upward pressure, the latter due to infiltration in the gravel bed below the silt in times of maximum river flood. The maximum downward pressure was due to a resultant 9-ft. head of water when the tanks were full and the river normal, and the maximum upward pressure was due to a resultant 7-ft. head of water when a tank was empty and the river at maximum flood. To meet the latter contingency, the floors of the tanks had all to be of such uniform weight per sq. ft. of surface as would counterbalance the upward pressure. The fact that the bearing resistance of the silt could not be utilised necessitated that the design of the tanks should embody a light reinforced construction for all walls and channels; and also required that no system of heavy beams should be adopted to carry the floors.

The cost of group piling to meet these various requirements by ordinary methods of construction was prohibitive. Sheet piling around the whole area was equally prohibitive, and did not supply any increase in the bearing resistance of the silt for the purpose of constructional operations. The only system that met all the requirements, and at the same time effected very considerable saving in cost, was the author's new system of reinforced concrete construction.

In this system there were no beams, no shear reinforcement, the maximum of flexural resistance with the minimum of steel reinforcement, and the minimum of bearing area of supports. These factors were attained, not by any new mathematical theory of internal stressing, but by the simple application of the principle that the stress transmission route of all load increments should be directly along the shortest line from the point of load application on the floor to the supports of the floor. The essential element of economy in the new system of construction resulted directly from the application of this principle.

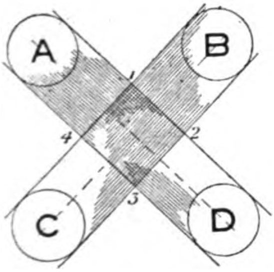


Fig. 1.

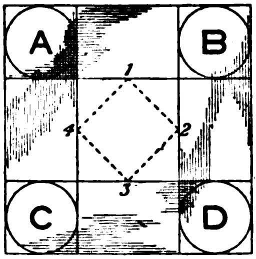


Fig. 2.

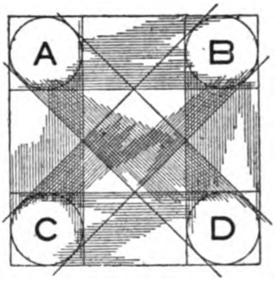


Fig. 3.

In the comparative type of ordinary construction, the like load increments were conveyed from a floor panel point across the floor panel to the panel beam, then turned round 90 deg. and conveyed along the cross beams to the main beams, and finally turned round 90 deg. and conveyed along the main beams to the supports. In consequence, the panel beams, cross beams, and main beams had all to be cumulatively strengthened as the load transmission route was lengthened, the result being increased weight and increased cost in steel and concrete. Mr. C. A. P. Turner saw this point, and endeavoured to approximate the ideal conditions in his admirable "mushroom" system of reinforced concrete floor construction. But he missed the really essential feature of economy, and the true application of what the author believed to be the first principle of structural engineering.

In *Fig.* 1, A, B, C and D were four supports of a floor. They were shown circular in plan, but might be square or octagonal in plan. The four areas might consist each of an area of group piling or of a concrete-filled cylinder or caisson for raft foundations, or of a tower of four or more legs carrying successive floors of factories, warehouses, hospitals, etc. In the last-mentioned case the tower was designed to be diaphragm-stiffened at each floor level—*i.e.*, internal to the tower area. Diagonally between supports A and D and between supports B and C, two bridging spans crossed at right angles. The area mutual to the two bridging spans was the area of the diagonal square 1, 2, 3, 4. The distance apart of the four supports must be such that the corners 1, 2, 3, 4 of the diagonal square lay approximately on the inner tangents to any two adjacent supports.

If the two diagonal bridging spans were rigidly connected and reinforced along the direction of their respective spans, half the load on the diagonal square 1, 2, 3, 4 was taken by each diagonal bridging span. It was equally obvious that this diagonal square 1, 2, 3, 4 was the area of maximum central flexure, and that the essential element of economy of the new system depended upon this halving of the load. In other words, they had effected in a practical manner the application of their first principle of construction, that the stress effect of a load increment be conveyed to supports along the most direct route of stress transmission.

In *Fig.* 2 was shown the application of the same principle to the four square spans between supports A and B, supports B and D, supports D and C, and supports C and A respectively. Combining the systems of reinforced bridging spans shown on *Figs.* 1 and 2, they obtained the complete system of reinforced construction shown on *Fig.* 3. The application of the first principle was thus seen to be a very simple matter, but it was always the simple application that yielded the highest efficiency.

The essential elements of design were (1) that each bridging span must be approximately of the width of a support; (2) that the reinforcing lines of each bridging span must be parallel to the axis of the span; and (3) that all bridging spans thus reinforced must cover the whole of the floor area between and over supports without any appreciable gap in the reinforcements. "Mushroom" systems failed to meet the essential conditions for economy by having a single column of ordinary proportions instead of a support of the width of the bridging spans. Turner gave his column support a "mushroom" head and a circular and radial grillage reinforcement area extending outwards, cantileverwise, into the floor, but this introduced transverse and other complicated flexural stressing in collecting the bridging span stress transmissions and conveying them to the supports.

The essential economy could only be attained by a rigid support the full width of the bridging spans. With this provision, the calculations for flexural stressing in the floor were infinitely more reliable than the calculations for a floor slab either freely supported or fixed on all four sides. The new system of construction eliminated all need for the ordinary complicated theory of flexure in floor panels, and also eliminated the need for the floor beams that had made the paradoxical theory of floor panel flexure necessary. For with the new system there were no beams between supports. The floor was thicker because the spans were longer. But shear reinforcement was unnecessary, and considerably less steel reinforcement was required for the purely flexural stresses, because the steel reinforcing wires were where they could be of most service, and did not at any place encumber the concrete with unnecessary reinforcement.

The supports adopted for the foundation system at the Leeds low-level sewage works consisted of reinforced concrete cylinders, 9 ft. external diameter and 8 ft. internal diameter, designed to sink half their depth through silt under their own weight when internally excavated. The cylinders were provided in cylindrical sections 3 ft., 4 ft., and 5 ft. long, the lowest section for a cylinder foundation being a standard 5-ft. section with a reinforced concrete cutting edge—it would have materially increased the cost to have supplied steel or cast-iron cutting edges. All cylinder sections were reinforced to stand sinking and handling in a vertical position, but not for rolling, as this would have added considerably to the cost without assisting the contractor's operations in any way. As events proved, the cylinders could be more easily handled vertically than by rolling.

The cylinder foundations were spaced, on an average, at 24-ft. centres. After sinking to the necessary levels in the gravel bed below the silt the cylinders were filled with concrete. Steel anchorages extended from the cylinder foundations into the floor system.

A Disclaimer.—Mr. Burnard Geen, M.Inst.C.E., of 122, Victoria Street, Westminster, consulting engineer, asks us to state that he is not, and never has been, in any way, either directly, or indirectly, connected with the "Westminster Finance Co., Ltd.," and that the references in the daily press on March 5 and 6 to "Bernard Geen" as London Secretary of the above-mentioned Company do not refer to him.

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

Paving Slabs.

Question.—We are wondering if you can put us in touch with any of your readers who could clear up a difficulty we are experiencing in the manufacture of concrete slabs for street paving. These units are made in wooden-sided steel-faced moulds, out of 3 in. to $1\frac{1}{16}$ in. to dust granite chippings and cement. The mixture is hand turned, as dry as possible, and after deposit the mould is vibrated by repeated hammering with a rammer on the sides of the mould. The mould, in preparation for receipt of the mixture, is coated on all contact faces with oil.

The slabs invariably turn out with more or less air-holes (or what appear to us to be air-holes) around the sides of the face of the flags, and more particularly on each of the four corners. We might mention that before the flags were vibrated a very poor face was produced; at present, employing the above method, the flags come away with a very good face except for the above holes.

We would very much appreciate advice on how to get rid of our trouble, at the same time manufacturing the slabs in open moulds, that is, without hydraulic pressure.—N. C.

Answer.—We would suggest that our inquirer should try putting down about $\frac{1}{2}$ in. of concrete at the bottom of the mould of a considerably wetter consistency in the first place, giving this a preliminary shaking, and then following up with the dry mixture. The explanation of the trouble may be that the concrete at the bottom is so stiff that the air bubbles cannot force their way up through it, and possibly if these were allowed to escape first through a much more plastic layer at the bottom the dry concrete could then be used on top without the formation of visible holes on the surface. We should be interested if our inquirer would make some experiments on these lines and report the results.

Further Correspondence. — Our answer, as above, was sent to our correspondent by post, who replied as follows:

We are much obliged for your communication dealing with the question of air holes appearing in the face of concrete flags we have been manufacturing. It is a remarkable fact that we have already put in execution the method suggested by you, having come to the decision that the top mixture was too heavy to permit the whole of the air to travel the full distance. We are pleased to say the method has met with singular success, and we are now turning out flags almost perfect in face so far as air holes are concerned.

Cracks at Corners.

We are still experiencing trouble, however, in other ways, one of the chief being a difficulty in getting a full batch to leave the moulds without sticking on the face.

Another difficulty we are experiencing is that cross-cornered fractures develop on some flags at the least handling. We were interested to read an article on this point in which it was pointed out that similar difficulties had been experienced in America, and were being overcome by turning to the manufacture of hectagon-shape pieces, which it was found were not more costly than the rectangular to make and lay.—N. C.

Answer.—As regards the moulds sticking and the fracture across the corners, we think both these point to the concrete being struck from the moulds too early, or at any rate when the concrete is too weak. This could be overcome by allowing the concrete a little longer for maturing before striking, or alternatively by allowing the maturing to take place in a warmer situation where hardening would proceed more rapidly.

Variations.

QUESTION.—Your reply to the following query would be of great interest :

Concrete for a special work is required to be of a proportion which will conform to the ratio 1 : 2 : 4. The local sand and stone are not well known (or alternatively the contractor's choice is large and the engineer writing the specification cannot tell what aggregates he will be offered). Suitable sand and stone having been selected eventually, it is found that a (say) 1 : 1½ : 4½ will give a better concrete for the work.

The contractor has tendered on a 1 : 2 : 4 concrete basis, and that price is the only one on which adjustment can be made (the inclusion of sand and broken stone as concrete aggregate in the schedule does not necessarily supply a solution).

How should the specification, bills of quantities, schedules, etc., read to meet this contingency ?—W. D. M.

ANSWER.—The difficulty could apparently be overcome by a clause in the specification to the effect that the engineer shall have the right to vary the proportion of sand to aggregate provided the ratio of cement to sand plus aggregate remains the same, and that such variation shall be made without any adjustment of price. As a matter of fact most specifications give the right to the engineer to make any variation that he thinks fit, and provide that the adjustment of price shall follow subsequently where such variation results in additional or reduced cost to the contractor ; in this case it would simply be a question of ascertaining the facts of the case and whether the variation did produce a cheaper or more expensive concrete.

Book Review.

The Erection of Engineering Structures and Plant. By Harry Atkin.

London : Chapman & Hall, Ltd. Price, 9*s*. 6*d*. net.

THE " Directly Useful Technical Series " is too well known to need any introduction, and this book is one of the series which covers a subject of considerable interest, but which hitherto has only been dealt with in a very general manner as an appendix to other subjects.

The book is primarily intended for the engineer who is in charge of a scheme and is called upon to deal with the erection of plant and control the actual handling of all kinds of tackle. It will be clear that it is very difficult for the office man to gain practical experience in all classes of erection during the early days of his career, and it will be an asset if a complete treatise is available which can be used as a reference when the site work is commenced.

The author describes the methods to be adopted in connection with cranes, winches, blocks, jacks, ropes, and sundry tackle, and then deals with the execution of various types of work, including structural work, bridge building, boiler fixing, and other items. Several chapters are also devoted to pipe work, including the tools and materials employed and their correct application.

We are not quite in accord with the writer as regards foundations and holding-down bolts, as the type of bolt box he recommends is not, in our opinion, as good as that generally adopted. The usual type of splayed box allows for the adjustment of the base plate, and this is a distinct advantage when perfect alignment is essential ; again, the bolt hole will be easier to fill, and therefore more thoroughly filled after the bolt is in position, if the hole is larger at the top. This is apart from the question of withdrawing the boxes from the concrete. In the case of very large bolt holes it is advisable to fill in with fine concrete for the lower portion and grout up after the initial set has taken place as this method will reduce shrinkage and make a stronger job.

With regard to the recommendation to use brickwork for machinery bases when the work has to be carried out during the week-end, the author has apparently overlooked the merits of the rapid-hardening Portland cements which are now available, and we do not consider the recommendation made can be justified.

The book is well illustrated throughout, and it should form a very useful addition to the engineer's library.—A. L.

Making a Dam Watertight.

A PAPER by Mr. P. W. Bertlin, A.M.Inst.C.E., to be brought forward for discussion at the Institution of Civil Engineers describes the construction of the new entrance, 140 ft. in width, to Messrs. Cammell, Laird & Company's wet dock at Birkenhead. The work involved the construction and removal of a temporary concrete coffer-dam; the construction of the new entrance for a sliding caisson, together with the caisson chamber and subsidiary works; and the removal of the existing wall.

It was decided that a block dam would be most satisfactory in view of the fact that a large proportion of the blocks would be subsequently used in the construction of the permanent work. The maximum head of water to be retained by the concrete dam was 44 ft. The width of the dam at the top was 11 ft. 3 in., and at the base 30 ft.

The foundation of the whole of the works was red sandstone. The dam was constructed under water by divers. The 5-ton blocks were designed so that each course was interlocked with the course below, and the standard block measured 7 ft. 6 in. by 3 ft. 8⅝ in. by 3 ft. 1½ in.

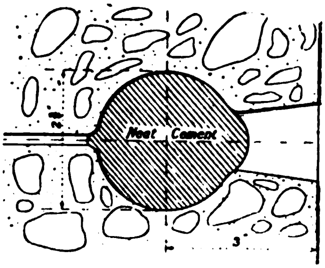
The site was cleaned and scoured by divers with water at high pressure. A foundation, about 1 ft. thick of 3-to-1 concrete was put in, and carefully levelled *in situ*. The first course of blocks was laid on this foundation on a bed of 1-to-1 cement mortar, to obviate risk of the dam sliding bodily on the foundation.

The method adopted for securing the watertightness of the dam is claimed to be novel, and proved successful. All the blocks were laid without any material between the joints (excepting only the bed joint of the bottom course); but the face blocks were cast with a groove and splayed to receive a cement "sausage" (as shown in the drawing). After a number of blocks had been set in position, a diver inserted lengths of calico bags in the grooves. The bags were generally about 17 ft. long for the horizontal joints and 4 ft. for the vertical joints. Cement grout was then forced into the bags with compressed air, at about 5 lbs. per sq. in. pressure.

Several advantages are claimed for this form of watertight joint:—

(1) The blocks can be laid "dry" much more rapidly than if bedded on any jointing material.
(2) Since the jointing is a separate operation from the block setting the setting gangs proceed with their work without interruption.
(3) A minimum of material is handled by the divers.
(4) Since the joints behind the "sausage" are open, no internal pressure occurs in the dam.

The dam, which was built in 5½ months, contained approximately 3,000 blocks, representing 8,122 cu. yds. of concrete. The average number of blocks set per week by two diving gangs was 137; and the maximum number per week was 255 blocks, containing 743 cu. yds. of concrete.



Scale One-Quarter Full Size

The existing wall, which was removed after the construction of the new entrance, was cellular in design, consisting of two parallel walls, with transverse walls 5 ft. wide at 20-ft. centres. To enable these walls to be removed by blasting as rapidly as possible, the necessary drilling was completed while the earlier stages of the work were in progress. Two rows of vertical holes, 6 ft. 6 in. apart longitudinally and 47 ft. deep, were drilled through the entire depth of the back and front walls. The distance apart of the rows was about 2 ft. 6 in., and, the holes in the two rows being staggered, the diagonal distance from hole to hole was 4 ft.

An Ingersoll wagon drill provided with a turntable base, reheater, and compressed-air hoist was used for this work. The drill had an 8-in. stroke, 5-in. bore, and delivered 250 blows per min. at 75 lbs. per sq. in. The solid hexagonal drills 2 in. diameter were provided with cross bits.

The holes were 4¾ in. diameter at the top and 3 in. at the bottom. A set of seven drills was used to drill a hole 47 ft. deep.

The bore-holes were washed out by a ⅜-inch diameter water-pipe terminating just above the top of the bit. High-pressure water was supplied by a direct-acting pump, carried on the drill wagon, and driven by compressed air. The usual rate of drilling was about 7 ft. per hour at the commencement of a bore, but the progress became slower as the depth increased. The average speed of drilling was 40 to 45 lin. ft. per diem.

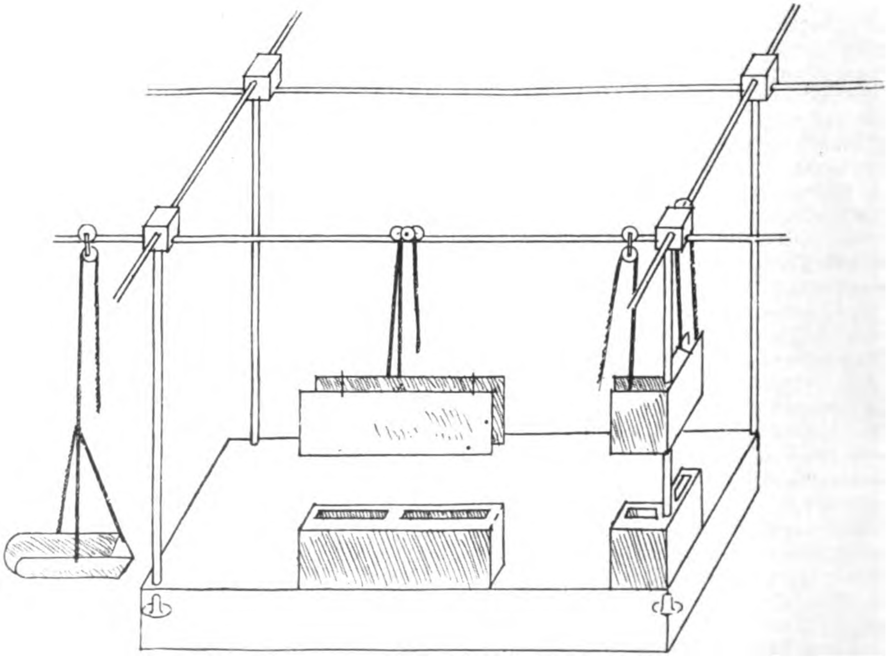
The holes in the river wall were charged in the following manner. A charge of gelignite was lowered into the bottom of the hole; a canvas bag of a diameter nearly to fit the hole, filled with sand, was lowered on top of this charge. This was followed by further charges of gelignite and sand tamping until the entire hole was filled. About 6 lbs. of gelignite was used for the bottom charge, and 1 lb. in the top charge, the intermediate charges grading between these weights. No. 7 submarine electric detonators were used, and the various charges were electrically connected in series, ensuring a simultaneous discharge. Immediately before joining the wires of the various charges, each circuit was tested with a galvanometer.

The results of the blasting were, on the whole, entirely satisfactory, enabling the dredging plant to deal with the removal of the débris.

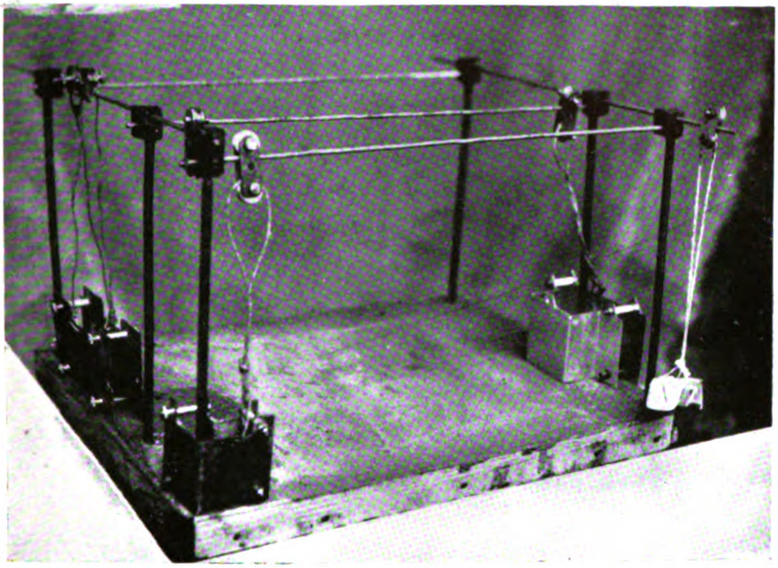
New System of Shuttering.

It is claimed that by the use of a new method of shuttering patented by Mr. Charles Allam, of Liverpool, the labour cost for fixing and unfixing the shuttering for an ordinary house is reduced by £10.

In this system, 6 in. lengths of pipe are sunk into the concrete foundation at centres decided by the plan of the house. These pipes are made with a flange on one end and screwed at the other end. The



New System of Shuttering.



Showing 1 *pair of Straight Shutters;* 1 *pair Corner Shutters;*
1 *Chimney Breast.*

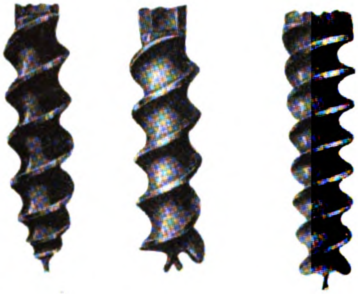
screwed end projects about 3 in. out of the concrete.

Lengths of metal pipe about 9 ft. long are fitted on to the projecting screws by means of a screw inside one end of the pipe. The pipes are screwed on the outside of the other end, to allow for a further length of pipe to be added if required. An arrangement made with holes to receive the steel bars is fitted on the top of each pipe, and these have set screws which hold the steel bars in position. The pipes are used to provide circulation through ventilators, in an endeavour to prevent condensation.

Steel bars about 1½ in. by ½ in. are fitted into fittings, and the shutters are worked from the bars by means of pulleys which fit on the top and run along the bars. Only one corner shutter and one straight wall shutter are required.

The suggested length of the straight shutter is 6 ft. long by 2 ft. deep. The size of the corner shutter would be determined by the design of the building. Rapid-hardening Portland cement and semi-moist concrete would be used and when the box is filled the workman withdraws the bolts and hoists the shuttering clear of the completed portion of the walls. The shutters are moved along by a grooved wheel-pulley on the bar overhead, dropped to the required position, the bottom bolts adjusted, and the work carried on. The top bolts are not removed. A stop-end is provided which fits on the end of the shutters, when required, making a box. By inserting a core block, any desired cavity can be produced. It is claimed for this method: (1) The initial outlay on plant is reduced by over one-half; (2) the work can be done more rapidly and more efficiently; (3) it can be worked entirely by unskilled labour.

A French Screw-Pile.

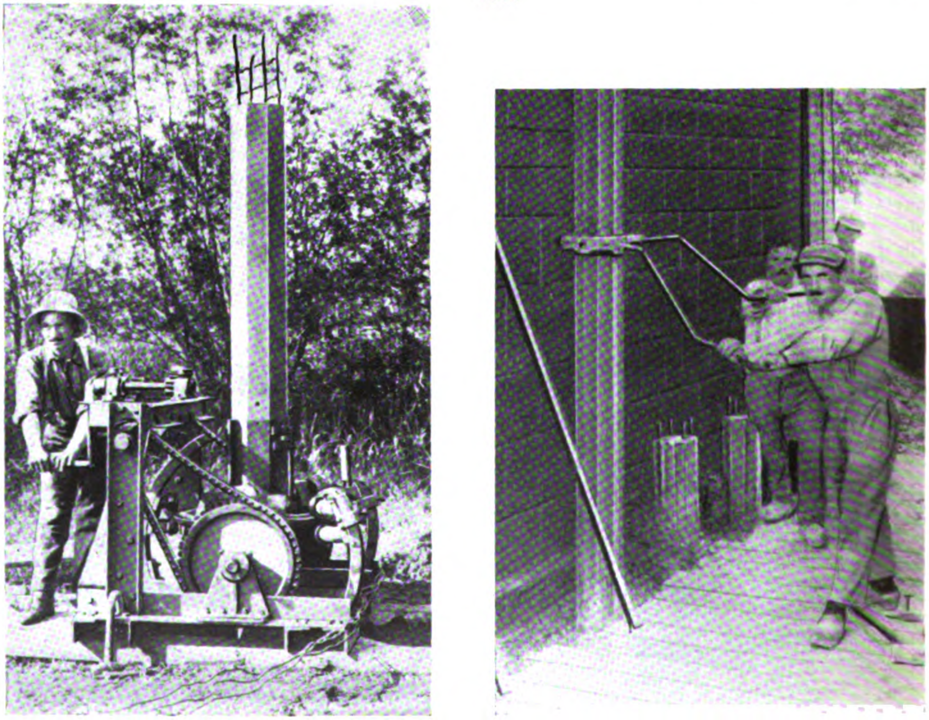


The Screw Ends.

We illustrate herewith a new type of reinforced concrete pile invented by M. Gustave Grimaud and marketed by M. J. Wyckmans, of Paris.

The feature of this pile is the screw end, which obviates the necessity for hammering. As will be seen, the screw is a double spiral, in order to avoid eccentric reaction during sinking and ensuring the pile being vertical. The amount of the reinforcement is determined by the degree of torsion to which the pile will be subjected during the process of screwing. The piles are pre-cast in a metal mould, which is shaped as a screw throughout the length of the pile which is to be sunk below ground-level and is retained and sunk around the pile.

This method of piling is particularly advocated for use in light or water-logged soil.



Driving Screw Piles.

Pioneer Roads for Mechanical Traction in Tropical Countries.

[*Contributed.*]

In countries which are being newly developed the question of load transportation is an urgent and important subject. The motor lorry has come to stay and demands access to the new fields, but the cost of a modern road over a considerable area of country is very great. It is with a view to assisting in the solution of the problem of laying a permanent road at a cost that is not prohibitive that the following suggestion is made.

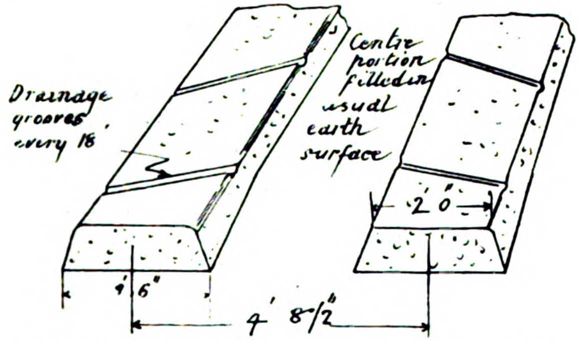
In the report of the East Africa Commission it is stated that the economical development of our vast resources there depends on the further provision of transport facilities. Suggestions have been made by the Empire Cotton Growing Corporation so far as mechanically-propelled vehicles are concerned, but the roadway has so far been conceived as essentially an earth road.

Condensing the main points discussed in the report of the Empire Cotton Growing Association, it may be agreed that railways cost £10,000 a mile and are run at a loss for the first ten years, while earth roads cost £2,000 a mile, and that it is not an economic or commercial proposition to build a railway in tropical Africa to carry a less tonnage than 2,000 a month. If this tonnage is to be obtained the railway must be fed from the surrounding country over what are at present very rough tracks, very often devoid of bridges or culverts.

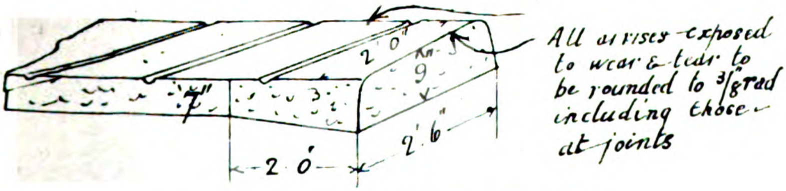
The maintenance of railways and earth roads in the Tropics is heavy, as due to the heavy rains experienced earth road maintenance costs are likely to be in the neighbourhood of £100 a mile.

The usual traffic on these earth roads is the ox-wagon drawn by a team of 16 oxen and containing some 7,000 or 8,000 lbs. of produce. Man-power is also used, but this means depriving the estates of valuable labour. Assuming a porter carries 70 lbs. for 100 miles in 6 days and returns in 5 days, it would take 128,000 men to carry 4,000 tons a six-day journey, or, in other words, the valuable labour on the estates is deprived of 1,408,000 man-days in order to get the produce to the railway.

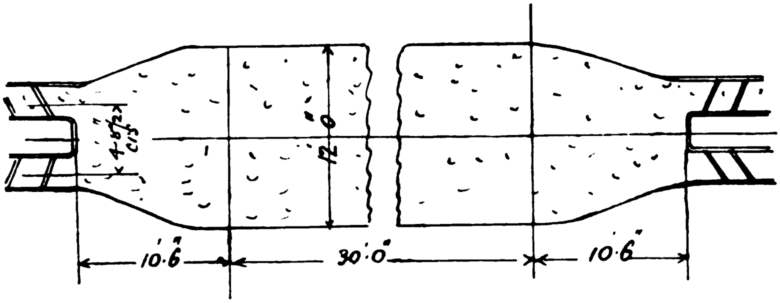
To obtain full benefit to the country


Drainage grooves every 18'
Centre portion filled in usual earth surface
2' 0"
1' 6"
4' 8½"

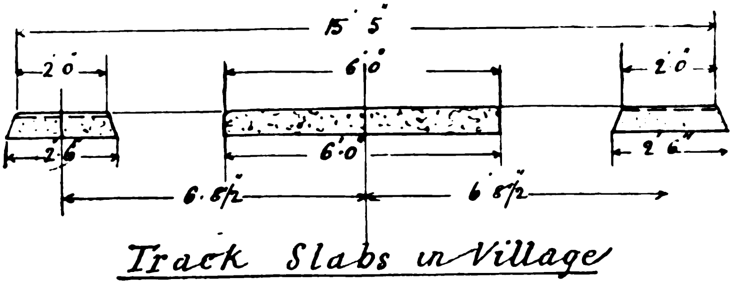
Concrete Track Slabs, Spaced 4 ft. 8½ in. Centres.


2' 0"
9
3
7"
2' 6"
2' 0"
All arrises exposed to wear & tear to be rounded to 3/8 rad including those at joints

End of Track Slab: Joints every 30 ft.



Widening at Passing Places: Five per mile.



as good a road as is possible is required at a low capital cost and requiring light maintenance. The first essential, if motor transport is to be used, is to standardise the load per inch width of wheel. The second essential, if the following suggestions were carried out, would be to standardise the width between wheel tracks; for instance, in the United States the standard width is 4 ft. 8½ in. from centre to centre. The cost per ton mile of light vans is greater than that of 4-ton lorries drawing a 2-ton trailer, hence the aim of the road engineer is to produce a road which by its cost justifies the use of 4-ton lorries and still shows a saving over an earth road used by light vans.

The suggestion is made that a standardised track should be laid down, constructed of slabs of concrete 2 ft. wide on the surface. At every 300 yds. a passing place constructed entirely of concrete would be provided, say 50 ft. long; this would be valuable more especially in the wet season. The same design as is adopted for passing places would be used in places where small fords had to be negotiated.

The space between the tracks and on each side would be the ordinary earth road, and the maintenance of the centre portion should be negligible as it would be tightly held by the concrete tracks. These tracks should have a series of grooves in the direction of the grade to ensure the centre being thoroughly drained, as otherwise the centre might become a watercourse in bad weather. In the swampy districts the tracks would have to be wider in order to distribute the load over a greater area.

The joints in the track slabs would be at every 30 ft., and at these points a slight thickening of the slabs would be desirable; the question of the necessity for reinforcement would be governed by the type of foundation. It is obvious that such a road would be available for lorries or ox-wagons, and the benefit to the community should justify the small capital cost.

As a rough guide to cost, the following figures are given :—

5 passing places per mile =	85 yds. run
5 bays of road tracks =	1,675 ,, ,,
	1,760 ,, ,,
5 passing places require. abt.	65 cu. yds. of concrete.
5 bays of road tracks require abt.	500 ,, ,, ,,
Total	565 ,, ,, ,,

Using 1 : 2 : 4 mix :

140 tons of cement at 80s.	= £560
500 ,, ,, stone ,, 10s.	= £250
250 ,, ,, sand ,, 10s.	= £125
	£935
Labour	£140
	£1,075

say £1,100 a mile.

The rough shaping of the roadway and making up of the remainder of the road as an earth road should not exceed £1,500 a mile; thus the pressing problem appears to be reasonably soluble at £2,500 a mile. As far as maintenance is concerned it should be reduced from £100 a mile to £50 at most, and the reduced cost of running lorries over such a track would be very considerable.

As this roadway approached a village with perhaps more concentrated traffic in the main street, the design would be the slightly more expensive, but still reasonable, form as sketched.

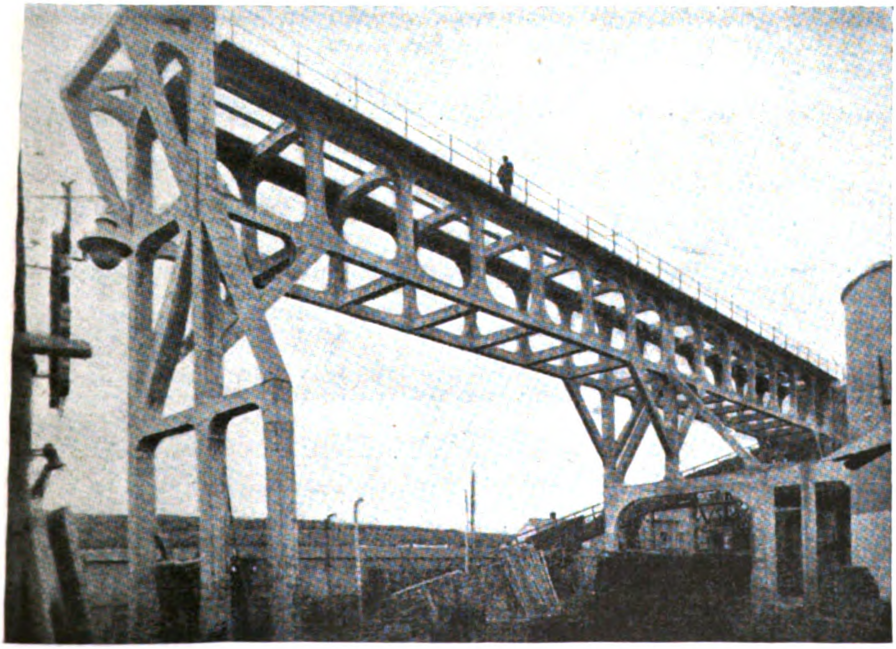
This design allows for fast motor traffic to continue along the centre, and lorries would travel with the near wheels on the near side concrete tracks.

It is thought that with these suggestions as a basis there should be no difficulty in obtaining a fairly permanent road, which would help to a more rapid development.

Gantry for 30-Ton Electric Crane.

THERE has recently been erected at the Tournai cement works in Belgium a crane gantry with some unusual features. The object of the management in erecting this crane was to decrease the cost of handling the limestone, which is delivered from the quarry by the Belgian State Railways, between the siding and the kilns. Space is very limited at the works and the design adopted has two spans only of 78 ft. with slender pillars.

According to " Revue de Beton Armé " the Vierendeel type of girder has been used with a depth of 13 ft., and cross bracing between the pair of trusses. Rail-level is at 49 ft. above ground. The supports are of the framed type resting on a reinforced concrete slab. The central support, as the illustration shows, has a clear opening of 26 ft. to allow trains to pass through. A special type of stop has been designed to act as a buffer in case of accident.—W.S.G.



DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	6
Thames ballast	,,	10	6
Broken brick (¾ in.)	,,	11	6
Best British Portland Cement	per ton 58s. to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	,, 100s. to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £20 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
9/16 in. to ½ in. Rounds	,,	10	9
⅜ in. Rounds	,,	11	0
¼ in. Rounds	,,	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per foot cube	1	11
Do.	do.	in columns	,, ,,	2	1
Do.	do.	in beams	,, ,,	2	3
Do.	do.	in floor slabs 4 in. thick	per yard super	6	0
Do.	do.	in floor slabs 5 in. thick	,, ,,	7	6
Do.	do.	in floor slabs 6 in. thick	,, ,,	9	0
Do.	do.	in floor slabs 7 in. thick	,, ,,	10	6
Do.	do.	in walls 6 in. thick	,, ,,	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
,, 7/16 in. to ½ in.	,,	21	6
,, ⅝ in. to 2⅞ in.	,,	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½d.; ⅜-in. rods, 1d.; ½-in. rods, 1¼d.; ⅝-in. rods, 1½d.; ¾-in. rods, 1¾d.; ⅞-in. rods, 2d.; 1-in. rods, 2¼d.; 1⅛-in. rods, 3d.; 1¼-in. rods, 3½d. (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1d.; ⅜ in., 2d.; ½ in., 2¼d.; ⅝ in., 3d.; ¾ in., 3½d.; ⅞ in., 4d.; 1 in., 4½d.; 1⅛ in., 6d.; 1¼ in., 7d. (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	,, ,,	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	,, ,,	1	1½
Do. do. as last, in narrow widths	,, ,,	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	,, ,,	0	3

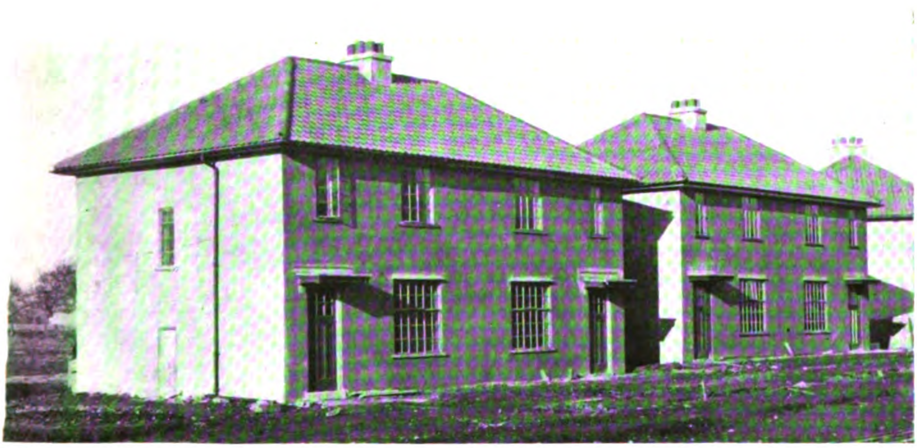
WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Concrete Houses at Gosport.

RAPID CONSTRUCTION.

Gosport, in common with the rest of the country, has its housing problem, and in searching for a solution the local authority has had to keep two factors—time and cost—well in view. Early in July last year, the site at Forton was a green field, where cattle grazed—now it has been completely changed. At the end of 1925 sixty houses were roofed and tiled, ten houses roofed ready for tiling, eight at wallplate level, fourteen had the foundations and the concrete over the site finished, and practically all the remainder are up to dampcourse level. It is expected that the scheme will be completed in May.



Concrete Cottages at Gosport.

The houses are being built by Messrs. John Laing & Son on their "Easiform" system, and the organisation is on the principle of mass production. To facilitate progress a rapid-hardening cement, "Ferrocrete," is used exclusively for the construction of the superstructure. In one part of the site carpenters are doing nothing else but cutting joists for the floors and roofs. In another men are engaged in riddling the sand and shingle ready for the concrete mixers; others are preparing the foundations, and still others are plastering and smoothing the surface of the concrete as the shutters are taken away ready for the next layer of concrete. Each man has his particular job, and as the processes advance each gang follows on, carrying out its particular work. The houses, in these circumstances, grow with amazing rapidity, and waste of labour and material is reduced to a minimum. This result has been achieved on a scheme of 122 houses. If the numbers were increased the result would be increased proportionately, as the system of construction is on a basis of approximately fifty houses, and for every additional fifty houses another set of shuttering is provided employing an additional gang of men.

It is proposed to erect forty-four houses of the parlour type and seventy-eight of the non-parlour type. The former will cost £471 each, and the latter £428. Thus the scheme will cost approximately £54,000, inclusive of footings, drains, and fencing, but exclusive of land, sewers, road development, etc. The road development will not be carried out until all the service pipes, gas, water, etc., have been laid, so that the surface when once it is laid will not have to be disturbed.

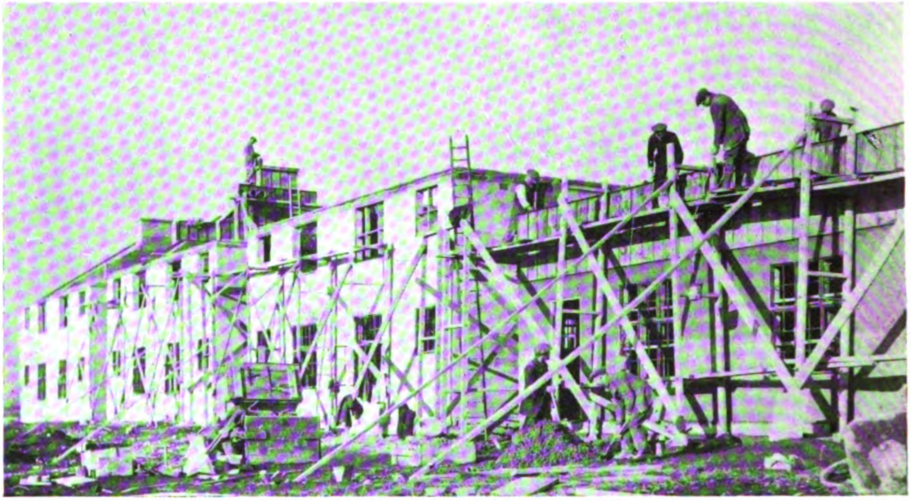
The houses are semi-detached, and in order to prevent monotony the frontage line is broken. They are built on concrete rafts laid on 2 in. of hard-core. The external walls are 8 in. thick, consisting of a 3-in. outer skin of shingle concrete and a 3-in. inner skin of clinker concrete, with a cavity of 2 in. between, both walls being tied together at regular intervals with galvanized ties. These walls are laterally reinforced with steel rods. The internal partition walls are also 3 in. thick, and are composed of reinforced clinker concrete. In view of a suggestion made at a Council meeting that the walls were not of sufficient thickness to be stable, one of the walls was belaboured with a heavy batten of wood, swung so as to give a most effective blow. The wood after the experiment was much the worse for wear, but the wall showed absolutely no signs of this rough and unusual treatment.

The outside walls are smoothed as the work proceeds, whilst the interiors are treated with a lime putty applied with a squeegee and thoroughly worked into the clinker concrete. This offers a firm surface suitable for distemper or for paper. The external walls are roughcast by unskilled labour.

The ceilings are of panelled asbestos sheeting, and the floors on the ground level are to be treated with a special composition of a warm red tint so as to obviate the need for floor covering. The window casements are of steel, so contrived that the exterior of the panes can be cleaned from inside. Red tiles are used for the roofs, laid on felt so that rain cannot drive in.

All the joinery work, stairs, cupboards, etc., have been made locally. In both types of houses a combination range will be fitted, and so fixed that when cooking is finished the grate can be made into an open fireplace. The scullery is fitted with a deep sink and a water heater, which gives a supply of hot water to the sink and automatically forces hot water to the bathroom. A gas cooker is included, and abutting on the scullery is a roomy pantry with outside ventilation. The bathroom is fitted with a white porcelain enamel bath, a lavatory basin, and w.c.

Three bedrooms have been so arranged as to give as much space as possible in the rooms, and a minimum of passage space. The rents are 9*s*. a week for the parlour type and 7*s*. 6*d*. for the non-parlour type, both exclusive of rates. The Ministry of Health has sanctioned loans for sixty years, the longest period even for brick buildings, for this method of construction.

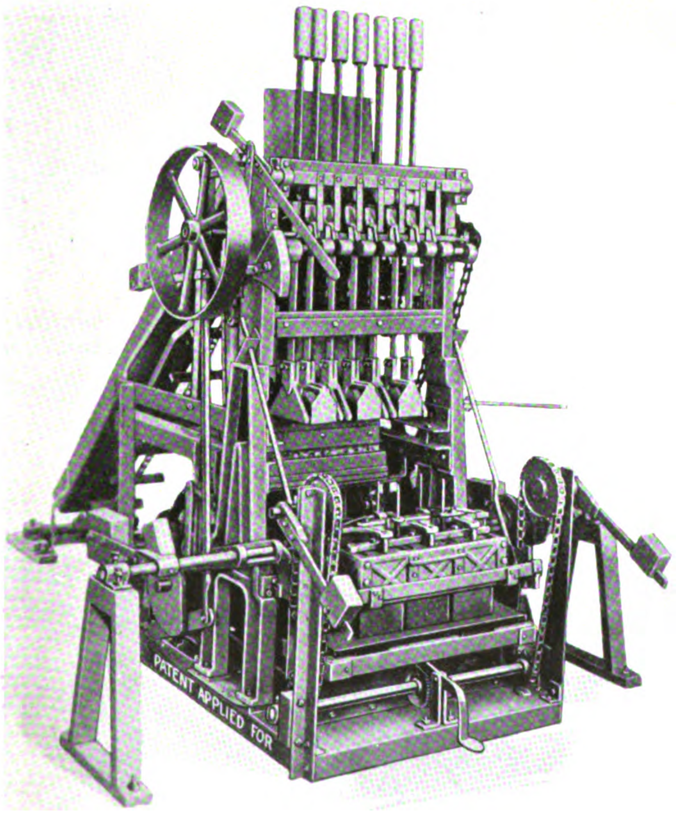


Concrete Cottages at Gosport during Construction.

Automatic Concrete Block Machine.

A NEW machine recently produced in the United States produces and delivers hollow concrete building blocks automatically. The concrete is fed into the conveyor at the back, and it is only necessary to insert the empty pallets in front and carry them away when filled. While the empty pallet is being exchanged for a full one, the machine is making the next batch of three blocks. Blocks of different dimensions can be made on the machine by changing the mould box and tampers of the machine.

The conveyor, which is located at the back of the machine, receives the material direct from the mixer and conveys it into a material hopper. The feeding-box slides below the material hopper and carries the concrete over the mould box where it is rammed into place by the tampers. The feed-box is then withdrawn, scraping off the excess material and carrying it back under the material hopper ready for the next charge. After the withdrawal of the feed-box the mould-box swings into the delivery position, bringing the bottom of the block into contact with a wood pallet which is placed on a balanced table. The machine then strips the three blocks downwards on to the pallet and at the same time pushes the pallet table down so that the blocks are clear of the mould-box, after which the mould-box immediately swings back into place, the feed-box comes forward, and the machine starts on its next



Automatic Concrete Block-making Machine.

cycle. The full pallet is removed and an empty one substituted while the machine is tamping the next set of blocks. It is not necessary to stop the machine, and there is no pause in its operation while the blocks are being removed. The machine is the product of the Ideal Concrete Machinery Co., of Cincinnati.

Building Trades Exhibition.

We may remind our readers that the Building Trades Exhibition is again being held at Olympia this year, from April 14 to 28. Among the firms in the concrete and allied industries who are exhibiting are:

Adamite Co., Ltd.
Australia Concrete Machinery and Engineering Co., Ltd.
British Fibrocement Works, Ltd.
British Steel Piling Co., Ltd.
Builders' and Contractors' Plant, Ltd.
Cement Marketing Co., Ltd.
Expanded Metal Co., Ltd.
John Fowler & Co. (Leeds), Ltd.
Joseph Freeman, Sons, & Co., Ltd.
Goodwin, Barsby & Co., Ltd.
Harvie Corporation, Ltd.
Indented Bar & Concrete Engineering Co., Ltd.
W. Kennedy (bar-benders).
Lafarge Aluminous Cement Co., Ltd.
Liner Concrete Machinery Co., Ltd.
Novocrete & Cement Products, Ltd.
Frederick Parker.
C. A. Peters, Ltd.
Stothert & Pitt, Ltd.
Triangular Construction Co., Ltd.
Winget (1924), Ltd.

The concrete block and slab-making plant on the "Winget" stand [Row "O" (No. 234)] will range from the simple "Westminster" machines and hand presses to the No. 3 automatic slab maker, with an output well above 200 per hour. The "Westminster" frogged brick machine and new concrete roofing tile machine will also be exhibited as well as the No. 1 vertical slab-making machine. The 1926 models of concrete mixers, also to be exhibited, include the latest type of semi-spiral wet mixer. This is a narrow-drum mix, and is driven by a "Lister" engine. It is portable, with rubber-tyred disc wheels. The "Warwick" 2½ cu. ft. mixer, engine driven, and the paddle-arm mixers of 3 cu. ft. and 4 cu. ft. batch capacity, will also be represented. Besides mixers and block-making machines, the stand will include various types of plant for reducing suitable materials to aggregate. There will, for example, be a combined clinker screening and crushing set, a No. 2 crusher (mounted on portable carriage) and a 40-ton screening plant for sand, gravel, clinker, etc., which is portable, self-elevating and engine-driven. Another great labour saving device is a small portable conveyor, suitable for handling bricks, blocks, sand, gravel, etc., and also for the rapid manipulation of all products in bulk.

TO ENGINEERS, CONTRACTORS, MACHINERY MERCHANTS, ETC.

FOR SALE: Four Ransome steel-framed concrete mixing and distributing plants, complete with towers, jibs, chutes, mixers, electric motors and winches, recently in use for the building of treble-storey ferro-concrete sheds at Gladstone Dock, Liverpool, and capable of depositing concrete within a radius of 150 feet and to a height of 66 feet. One of the plants is still working and all the plants may be inspected on application to: The Engineer-in-Chief, Mersey Docks & Harbour Board, Dock Office, Liverpool.

Prospective New Concrete Work.

Abingdon.—*Houses.*—The T.C. has applied for sanction to a loan of £20,500 for the erection of 36 houses at Boxhill.

Aldershot.—*Houses.*—The T.C. has applied for permission to erect 30 houses by direct labour. The estimated cost is £525 per house.

Atherstone.—*Houses.*—The R.D.C. is preparing a scheme for the erection of 145 houses.

Batham Gate.—*Concrete Cottages.*—The Chapel-en-le-Frith R.D.C. proposes to build 6 concrete cottages.

Baslow.—*Road.*—A road is to be constructed from Calver Road to Back Lane.

Bridgwater.—*Houses.*—The T.C. proposes to erect 100 houses.

Cardiff.—*Road.*—The Corporation has applied for sanction to borrow £75,000 for the construction of a road from The Hayes to Frederick Street.

Chester.—*Houses.*—The City Council has applied for a loan for the construction of a reinforced concrete raft for the houses to be erected on the Cherry Grove site.—The Corporation has applied for sanction to a loan of £68,016 for housing purposes.

Chichester.—*Houses.*—The Corporation has applied for sanction to erect 50 houses in Kingsham Road.

Conway.—*Houses.*—The Borough Surveyor has been instructed to prepare a scheme for the erection of 60 houses.

Croydon.—*Concrete Wall.*—The C.B. proposes to erect a concrete wall at the depot in Rockmount Road. The cost is estimated at £910.

Dalmuir.—*Houses.*—The Clydebank Corporation is negotiating for the purchase of a housing site.

Dorchester.—*Houses.*—The Corporation proposes to erect 54 houses.

Dornie.—*Bridge.*—A bridge is to be constructed over Loch Long, near Dornie, at an estimated cost of £30,000.

Dunbar.—*Promenade.*—The T.C. proposes to construct a promenade at St. Anne's.

Eastbourne.—*Sea Defence Works.*—A scheme is being considered for strengthening the sea defences at Langney Point.

Ellesmere Port. — *Houses.* — The U.D.C. has applied for sanction to borrow £27,100 for housing purposes.

Felling.—*Houses.*—The U.D.C. is considering a scheme for the erection of 338 houses. The cost is estimated at £190,753.

Galloon Island.—*Bridge.*—The Fermanagh C.C. proposes to spend £3,000 on the construction of a bridge from the mainland to Galloon Island.

Glasgow.—*Concrete Bridge.*—The Corporation proposes to erect a reinforced concrete bridge in place of the existing Queen Marget Bridge. The approximate cost is £80,000.

Guildford.—*Houses.*—The Corporation proposes to spend £28,000 on the construction of 56 houses.

Hayes.—*Houses.*—The U.D.C. proposes to build 100 houses.

Hebburn.—*Houses.*—The U.D.C. has applied for a loan of £32,265 for the construction of 77 houses on the Black Road site.

Heysham.—*Sea Wall.*—The U.D.C. has applied for sanction to erect a sea wall and promenade.

Hereford.—*Houses.*—The City Council proposes to erect 137 houses, at a cost of £75,000.

Inverary.—*Sea Wall.*—The T.C. is considering a scheme for the construction of a pier and sea wall.

Kingsclere. — *Bridge.* — The R.D.C. has instructed the Surveyor to prepare plans for a bridge across the Courseford Water, at Kingsclere.

Kiveton Park.—*Houses.*—The R.D.C. has applied for sanction to a loan of £21,000 for the erection of 48 houses at Dinnington.

Llangollen.—*Houses.*—The R.D.C. is seeking permission to borrow £45,510 for the construction of 96 houses.

Luton. — *Houses.* — The T.C. has applied for sanction to a loan of £155,810 for the construction of 254 houses.

Martley.—*Houses.*—The R.D.C. has applied for sanction to a loan of £16,000 for the construction of 40 houses.

Morley.—*Houses.*—The T.C. is negotiating for a site for the construction of 200 houses.

Newcastle-on-Tyne. — *Bridge.* — The Corporation is considering a proposal to construct a bridge across the Ouseburn Valley, at Jesmond. The cost is estimated at £400,000.

Oswestry.—*Reservoir.*—The T.C. has applied for a grant towards the cost of constructing service reservoirs, filtration plant, etc.

Tenders Accepted.

Bakewell.—*Concrete Reservoir.*—The R.D.C. has accepted the tender of Messrs. C. Collins & Co., Radcliffe, at £9,147, for the construction of a reinforced concrete reservoir with a capacity of 750,000 gallons.

Bristol.—*Concrete Houses.*—The T.C. has accepted the tender of Mr. J. Knox for the construction of 600 concrete houses.

Burnley.—*Concrete Raft.*—The T.C. has accepted the tender of Messrs. Rainey Bros., Barrow-in-Furness, at £2,083, for the construction of concrete rafts.

Canterbury.—*Concrete Houses.*—The T.C. has accepted the tender of the Triangular Construction Co., Ltd., at £25,500 for the construction of 60 concrete cottages.

Dundee. — *Concrete Houses.* — The Housing Committee has recommended for acceptance the tender of Messrs. Henry Boot & Sons for the erection of 1,000 concrete houses. The cost is estimated at about £500,000.

Glasgow.—*Concrete Houses.*—The Corporation has accepted the tender of the Balshagray Building Co. for the erection of concrete houses. The cost of each house is £409.

Glenarm.—*Concrete Bridge.*—The Antrim C.C. has accepted the tender of Messrs. McLaughlin & Harvey, Ltd., at £1,297, for the reconstruction of a bridge in reinforced concrete.

Hilton.—*Buildings.*—The tender of Messrs. Clark & Chapman, of Aberdeen, at £4,371, has been accepted for reinforced concrete work in connection with the construction of two hostels and buildings for the National Committee for the Training of Teachers.

Huddersfield.—The T.C. has accepted the tender of Messrs. Mark Brook & Sons, Ltd., for concrete work at the cold stores.

Leeds.—The T.C. has accepted the tender of Messrs. Sugden, Son & Co., at £1,340, for reinforced concrete work in connection with the construction of a public wash-house at Stocks Hill, Holbeck.

Leith.—The Leith Dock Commissioners have accepted the tender of Messrs. Melville, Dundas & Whitson, at £75,441, for the construction of reinforced concrete warehouse and silos adjoining the East Quay.

Newport, I.O.W.—*Concrete Wall.*—The B.C. has accepted the tender of Messrs. A. Fasey & Son, Ltd., Leytonstone, at £3,422 18*s*., for the construction of a reinforced concrete wall on the east side of the River Medina.

Penarth. —*Esplanade.*—The U.D.C. has accepted the tender of Mr. F. J. Thomas, Cardiff, at £22,974 13*s*., for widening the esplanade in reinforced concrete.

Poplar (London).—*Retaining Wall.*—The B.C. has accepted the tender of Messrs. K. Holst & Co., at £3,564, for the construction of a reinforced concrete retaining wall.

South Shields.—The T.C. has accepted the tender of Messrs. G. Thornton & Co., S. Shields, at £538 10*s*., for reinforced concrete foundation work at the electricity works.

Watford.—*Concrete Foundations.*—The T.C. has accepted the tender of the Industrial Constructions, Ltd., at £2,470, for reinforced concrete foundation work at the new power station.

Winchester.—*Concrete Cottages.*—The Corporation has accepted the tender of the Monolithic Concrete Houses Co., at £16,212, for the erection of 42 concrete cottages at Bar End.

Trade Notices.

Plant for South America.—The Ransome Machinery Co. (1920), Ltd., have received an order from Messrs. S. Pearson & Son, Ltd., for two No. 0 size and four No. 1 size "Ransome" concrete mixers fitted with electric drive, and also ten Ransome tip carts for use on their contract, Cia Hidro-Electrica, Volcan, Santiago, Chili, South America.

Steel Forms.—We are asked to state that the steel forms used for the construction of the new Trafford Wharf, illustrated and described in our last issue, were "Blawforms," supplied by Messrs. Christmas & Walters, Ltd., of Caxton House, Westminster, S.W.1, who are the sole agents in Great Britain for the Blaw-Knox Company. The Blawforms as illustrated in the article "Design of Formwork" in our March issue are also obtainable from Messrs. Christmas & Walters, Ltd.

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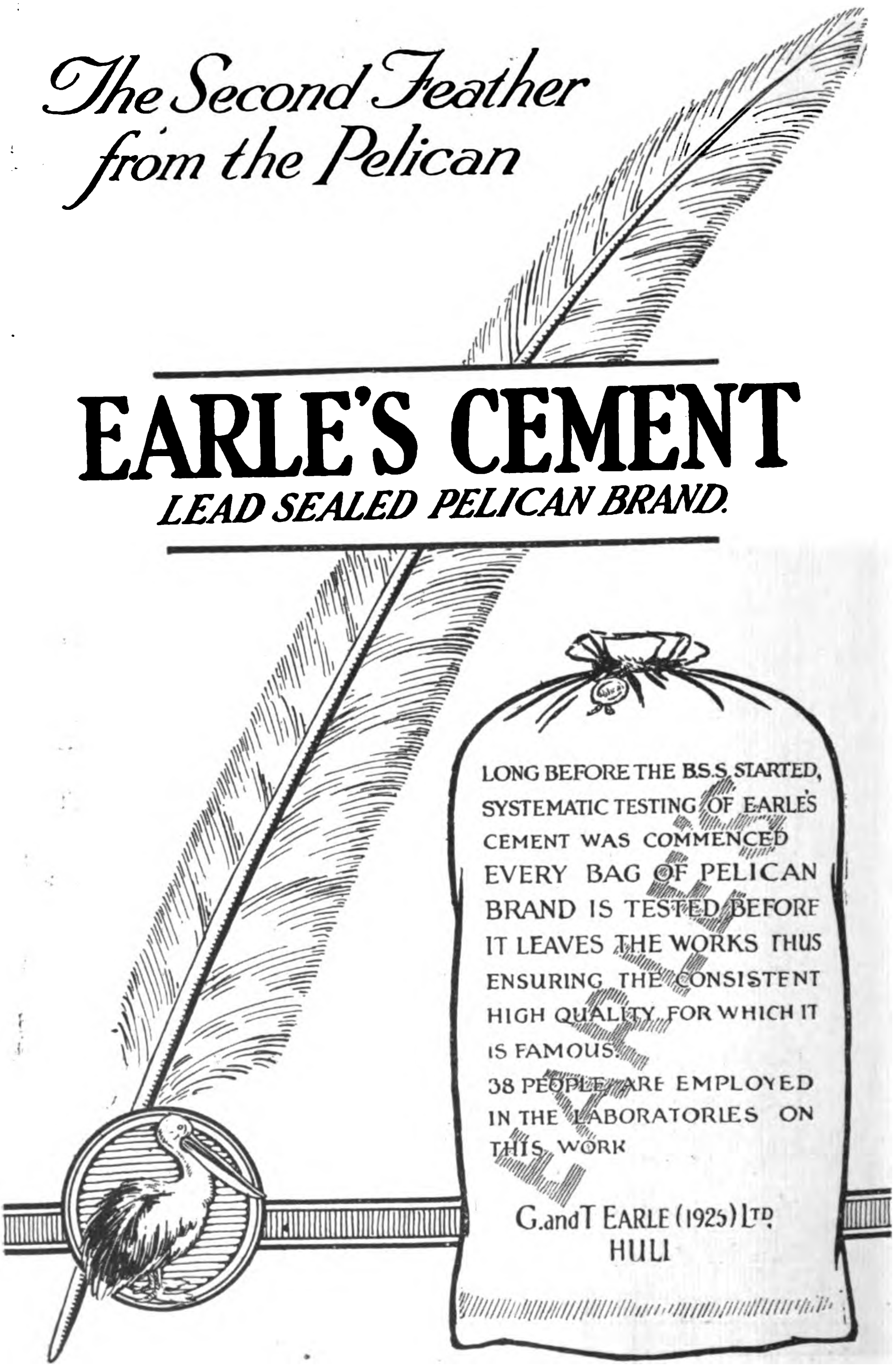

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CONCRETE
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Volume XXI. No. 5. LONDON, MAY, 1926.

EDITORIAL NOTES.

Design of Engineering Structures.

So many engineering structures and purely utilitarian buildings have now been erected without giving offence to the eye of the man in the street, and even earning the praise of eminent architects, that one is surprised to see a discussion on the design of such buildings opened with a paper entitled " The Ugliness of Engineering Structures." Yet such was the title of a paper read before the Society of Engineers last month by Mr. H. B. Creswell, F.R.I.B.A. The lecturer's prejudices are clearly indicated by his selection of title, yet paradoxically enough he found many engineering structures to commend as of beautiful design in the course of his remarks. With many of his opinions we agree, such as : " The beauty of an engineering structure depends, among other conditions, upon the integrity and appropriate use of materials and nice adjustment of the form of the structure to its uses and the forces acting upon it, from which it follows that beauty can only be present in a work of engineering the design of which displays high efficiency and economy of means to ends." But we find it difficult to reconcile this statement with many of the lecturer's other remarks. Speaking of the dam of the Caban Reservoir, he said : " If we imagined the masonry to have been replaced by armoured concrete, we were instantly aware of a great weakening in our sense of the beauty of the structure. This was partly due to our sympathy for masonry, but it was mainly due to the dam being no longer a structure of separate live units, the nature of which we understood, but a hulking monolith beyond sympathetic comprehension. Our sense of the dam was further confused by its form not being characteristic or expressive of the qualities of armoured concrete, but imitative of the form of a masonry dam ; it was making an appeal to our sense of separate stones piled up to counterbalance by their dead weight the thrust of a mass of water, when it was nothing of the sort."

If local stone had not been so plentiful and reinforced concrete had been found to " display the highest efficiency and economy," and if a reinforced concrete dam had been built which showed " integrity and appropriate use of materials and nice adjustment of the form of the structure to its uses and the forces acting upon it "—what then ? The critics of reinforced concrete cannot have it both ways. If it is their creed that the economical and rightful use of materials is the essence of beauty, they must accept a structure as beautiful when these requirements have been met. The average man will find it difficult to understand the statement that a masonry dam gives the impression of being a structure of separate live units and why the same structure carried out to the same design in reinforced concrete blocks must necessarily be a "hulking monolith."

Concrete for Private Street Works.

A GREAT deal of interest has been aroused by the Maldens and Coombe Urban District Council private street works case (reported in our March issue). Writing to the Press on the subject, Mr. E. J. Elford, M.Inst.C.E., Borough Engineer of Wandsworth, points out that the opponents of the scheme to carry out the works in concrete cared little what kind of a road was provided, so long as the cost was brought down to the lowest possible figure, and having regard to the fact that they are mostly owner-occupiers of small means who have bought their houses at a high price, he thinks they are entitled to sympathetic consideration. The point which appears to have been passed over very lightly, is that in the circumstances of the particular case concrete is the cheapest form of reasonably satisfactory construction. This was, in fact, the object of the Council in adopting this class of material.

Much stress was laid by the appellants upon the fact that the Ministry of Health specification for private streets provided for a hardcore foundation and tar-macadam surface, and it was argued that this form of construction should have been good enough for the Council. In this connection, Mr. Elford produces evidence to the effect that, with a view to reducing the burden upon frontagers, his Council had explored most thoroughly every avenue which appeared to open up possibilities of cheapening construction, while providing reasonably durable and satisfactory roads. As a result, alternative tenders were invited for (*a*) carriageways to a somewhat less stringent specification than that recommended by the Ministry of Health, and (*b*) carriageways of concrete. Ten streets were included, and it was found that in the case of eight streets concrete showed a saving of £1700, which represented a saving of about 10 per cent. upon the total cost and nearly 20 per cent. upon the cost of carriageways alone. It was clear from the evidence that the determining factor was whether there was already in the streets any carriageway foundation which could be allowed to remain, and in the case of the eight streets referred to there were practically no existing foundations. In regard to other streets where foundations had already been provided, the hardcore–tar-macadam form of construction was found to be cheaper.

Mr. Elford expresses the opinion that in practically all cases where foundations are absent, concrete will be found cheaper than even hardcore and water-bound macadam, and certainly much more satisfactory, and this is the view of many other Borough Engineers and Surveyors. Concrete has been used for private and back streets in a large number of towns, including Sheffield, Barnsley, York, Goole, Gosport, Rhyl, Wandsworth, Hoylake, and Skegness, and the reason is obvious from the following figures. In the case of Hoylake the cost of a concrete carriageway, 6in. thick, is estimated at 3*s*. per square yard less than tar-macadam on pitching. Concrete kerbs were substituted for stone kerbs at 1*s*. per lineal yard less, in addition to the saving of 7 in. of paving. In Barnsley the cost varies from 15*s*. 3*d*. per super yard to 20*s*. 6*d*., compared with the cost of 23*s*. to 24*s*. 11*d*. per square yard for sett-paved roads in that town. Bolton-on-Dearne's estimate of cost ranges from 13*s*. to 22*s*. per square yard. Lower initial cost thus goes hand in hand with the almost negligible maintenance costs of a concrete surface.

Problems in the Theory of Construction.

By Ewart S. Andrews, B.Sc., M.I.Struct.E., A.M.Inst.C.E.

A BENDING MOMENT PROBLEM.

ALTHOUGH the following problem has probably been solved by a number of writers, we do not think it is usually to be found in the text-books commonly used by British students, and as the writer has been asked more than once by students to explain this case it might be of sufficient interest to students to treat the problem at some length.

The problem is to find the B.M. and shear diagrams for a beam which is simply supported at one end and fixed (sometimes called "encastré") at the other end, the load being distributed and increasing uniformly in intensity from zero value at the simply-supported end to a maximum value at the other end This problem arises in practice in the design of retaining walls which are supported at the top and of the sides of covered tanks and bins.

Fig. 1 represents the loading, and the intensity of the loading is p at unit distance from the freely-supported end R; at the end L the intensity of load is pl and the total load W, which is represented by the area of the triangular load diagram is $pl \times \frac{l}{2} = \frac{pl^2}{2}$.

METHOD I. MATHEMATICAL METHOD BY DEFLECTIONS.

In this method we first imagine the support at the end R to be removed. Now consider a point P at distance x from the point R.

The bending moment B at this point is equal to the moment of all forces

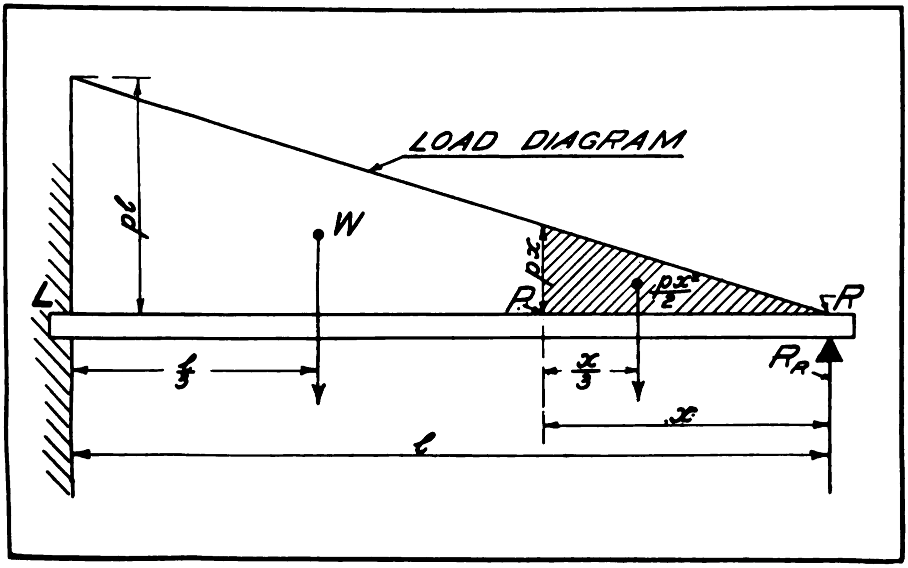


Fig. 1.

to the right of P; the intensity of load at P is equal to px and the total load to the right is represented by the area of the shaded triangle and is equal to $px \times \frac{x}{2} = \frac{px^2}{2}$. It acts at the centroid of this triangle which is at distance $\frac{x}{3}$ from P so that $B = \frac{px^2}{2} \times \frac{x}{3} = \frac{px^3}{6}$.

We now have

$$EI\frac{d^2y}{dx^2} = B = \frac{px^3}{6} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\therefore\ EI\frac{dy}{dx} = \int Bdx$$

$$= \frac{px^4}{24} + C_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$EIy = \int\int Bdx\,.\,dx$$

$$= \frac{px^5}{120} + C_1x + C_2 \,. \quad . \quad . \quad . \quad . \quad (3)$$

Now $\frac{dy}{dx} = 0$ when $x = l$

$$\therefore \text{ from (2) } C_1 = -\frac{pl^4}{24} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and $y = 0$ when $x = l$

$$\therefore \text{ from (3) } 0 = \frac{pl^5}{120} - \frac{pl^5}{24} + C_2$$

$$\therefore\ C_2 = \frac{pl^5}{24} - \frac{pl^5}{120}$$

$$= \frac{pl^5}{30} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$\therefore$ At the end R where $x = 0$ we have from (3)

$$EIy = \frac{pl^5}{30}$$

$$\therefore \text{ End deflection } = \frac{pl^5}{30EI}$$

$$= \frac{Wl^3}{15EI} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

because $W = \frac{pl^2}{2}$.

Now if R_R is the end reaction, it acting alone must produce at the end an upward deflection equal to $\frac{R_R l^3}{3EI}$, this being the standard case of a cantilever with an isolated end load. As therefore the end deflection must be zero it is clear that these two deflections must be equal, so that

$$\frac{R_R l^3}{3EI} = \frac{Wl^3}{15EI}$$

$$\text{or } R_R = \frac{W}{5} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

In order to find the negative bending moment at the fixed end we take moments about the point L and obtain

$$B_L = R_R \times l - W \times \frac{l}{3}$$

$$= \frac{Wl}{5} - \frac{Wl}{3} = -\frac{2Wl}{15}$$

$$= -\cdot 133Wl \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

The maximum positive bending moment will occur at the point at which the load between it and the end R is equal to the reaction $\frac{W}{5}$

i.e.

$$\frac{px^2}{2} = \frac{W}{5} = \frac{pl^2}{10}$$

$$\therefore\ x^2 = \frac{l^2}{5}$$

$$x = \frac{l}{\sqrt{5}} = 0{\cdot}447l \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$\therefore\ B_{max} = \frac{W}{5} \,.\, x - \frac{W}{5} \,.\, \frac{x}{3}$$

$$= \frac{2Wx}{15}$$

$$= 0{\cdot}06\ Wl \text{ (approx.)} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

The B.M. at any point P at distance x from the end is given by the relation.

$$B = \frac{Wx}{5} - \frac{px^3}{6}$$

$$= \frac{Wx}{5} - \frac{3l^2}{Wx^3}$$

$$= Wx\left(\frac{1}{5} - \frac{x^2}{3l^2}\right) \quad . \quad . \quad . \quad . \quad . \quad (11)$$

This gives the following values, from which the diagram shown on *Fig.* 2 has been drawn.

$\frac{x}{l} =$	0	·1	·2	·3	·4	·5	·6	·7	·8	·9	1·0
$B = Wl \times$	0	·020	·037	·051	·059	·058	·048	·026	− ·011	− ·063	− ·133

The shear at P is given by

$$S = \frac{W}{5} - \frac{px^2}{2}$$

$$= \frac{W}{5} - \frac{Wx^2}{l^2}$$

$$= W\left(\frac{1}{5} - \frac{x^2}{l^2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \qquad (12)$$

The resulting diagram is a parabola.

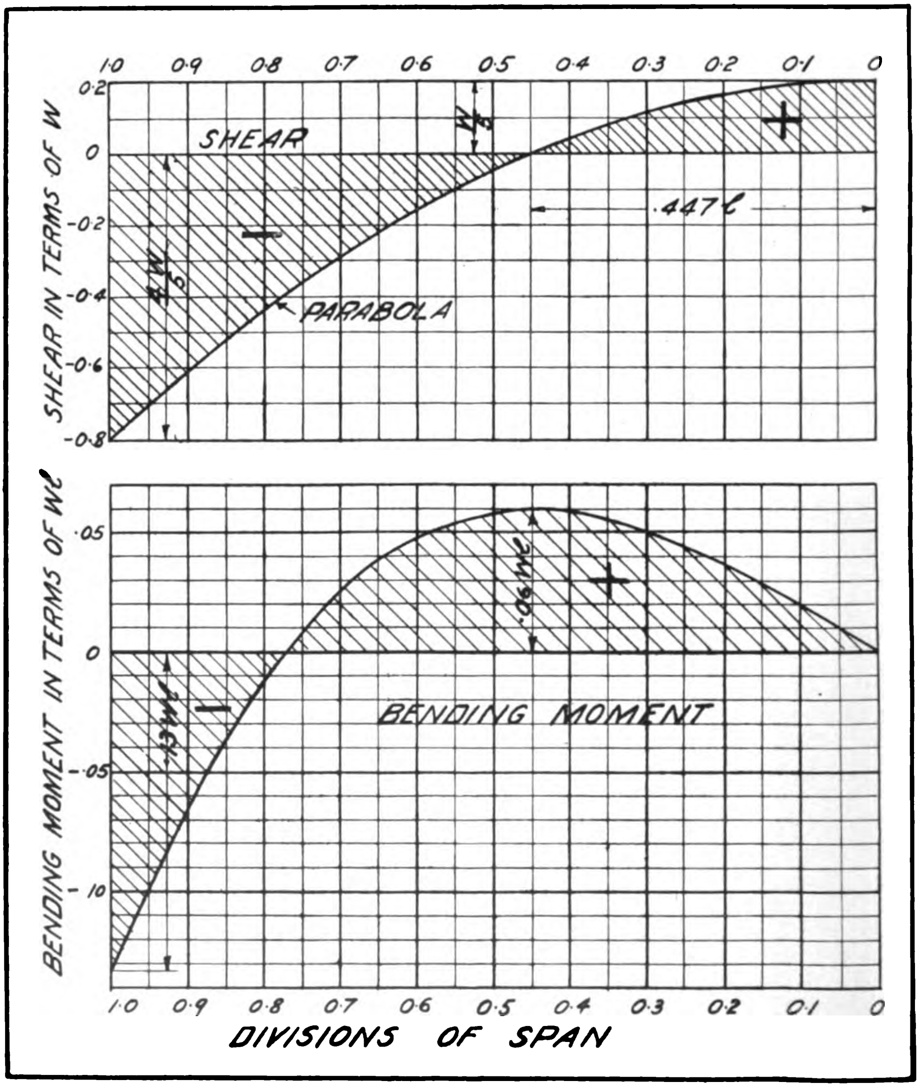


Fig. 2.

METHOD II. MOHR'S METHOD OF DEFLECTIONS.

According to Mohr's method we regard the B.M. diagram as an imaginary load system and obtain the deflection by finding the resulting imaginary bending moment at the point in question and dividing by *EI*. In the case of the cantilever the fixed end has zero slope and deflection and this has to be taken as the free end of the imaginary cantilever.

Now the B.M. diagram for a cantilever carrying a load increasing in intensity uniformly from zero to a maximum value is a "parabola of the third order," the bending moment being proportional to the cube of the distance from the "free" end; the area of a parabola of the third order is ¼ times the base multiplied by the depth and its centroid occurs at a distance of ⅘ of the base from the "free" end. We can thus calculate in the following manner the deflection at the end *R* of the beam if the support is removed. *Fig.* 3 represents the imaginary load diagram.

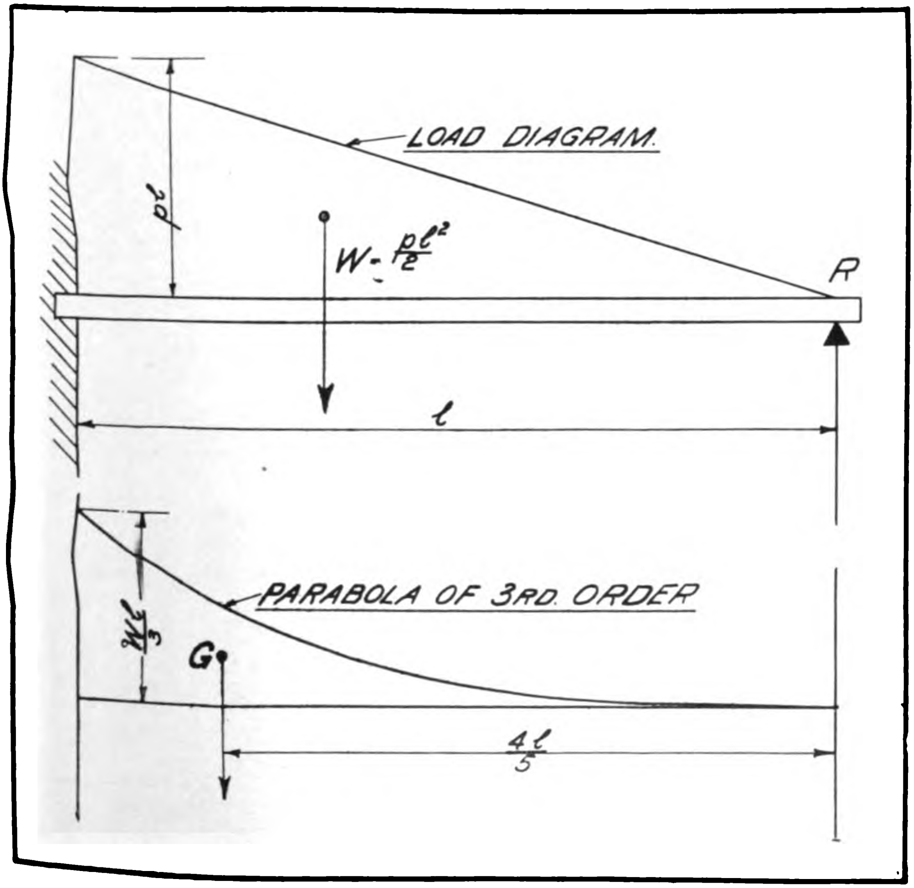


Fig. 3.

Then total imaginary load

$$= W^1 = \text{area of imaginary load diagram}$$

$$= \frac{Wl}{3} \times \frac{l}{4} = \frac{Wl^2}{12}.$$

This acts through its centroid G.

∴ Imaginary B.M. at point R

$$= W^1 \times \frac{4l}{5}$$

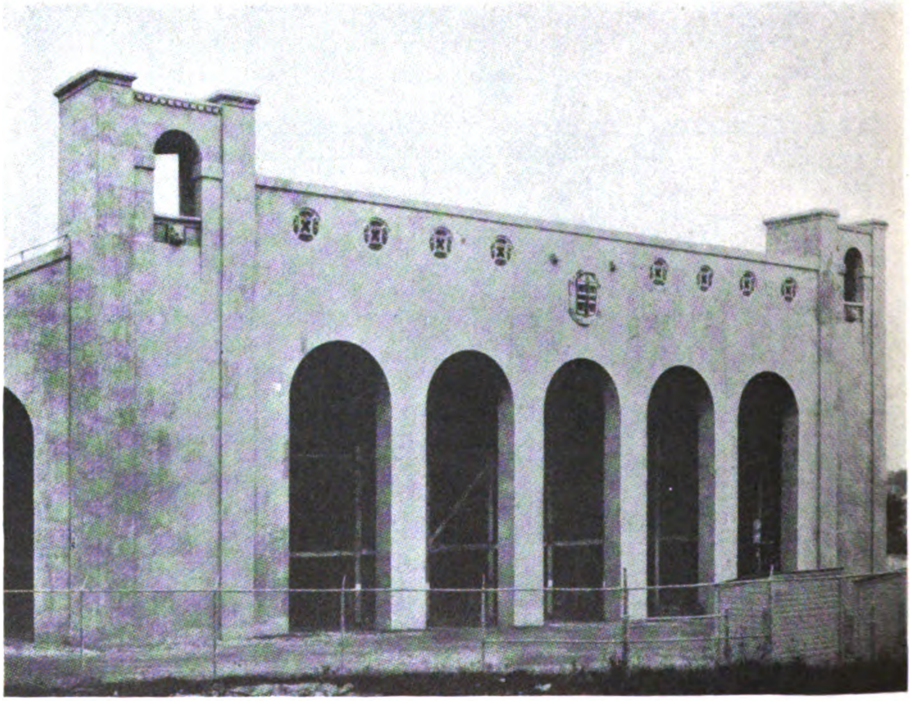
$$= \frac{Wl^2}{12} \times \frac{4l}{5}$$

$$= \frac{Wl^3}{15}$$

∴ deflection at R if support is removed

$$= \frac{Wl^3}{15EI}.$$

This is the same result as we obtained in equation (6) by the previous method, and we then proceed as before to ascertain the value of the end reaction R_R and thus the values of the shear and bending moment at any point.



[*Mr. G. Hadden, Engineer; M. Paul Cret, Consulting Architect.*

Entrance to a Stadium in Reinforced Concrete.

Beam and Slab Concrete Highway Bridges.

By Sir E. OWEN WILLIAMS, K.B.E., B.Sc., M.Inst.C.E.

In a recent issue of the *Journal of the Institution of Municipal and County Engineers*, Sir E. Owen Williams deals with the question of the design of highway bridges to carry Ministry of Transport loading, and we take the following from his article, by permission :

When to use beams and slabs as against solid slab construction, what centres to put beams if beams are used, are economic questions which arise in the design of small span concrete bridges. The very flexibility of reinforced concrete as a designing medium makes it difficult to settle such questions without a general investigation into cost. There are no standard sections of beams or troughing to guide the designer ; he is free to make sections as he pleases and at any spacing. Indeed, it is at once the delight and difficulty of the material that it is so untrammelled with conventional dimensions.

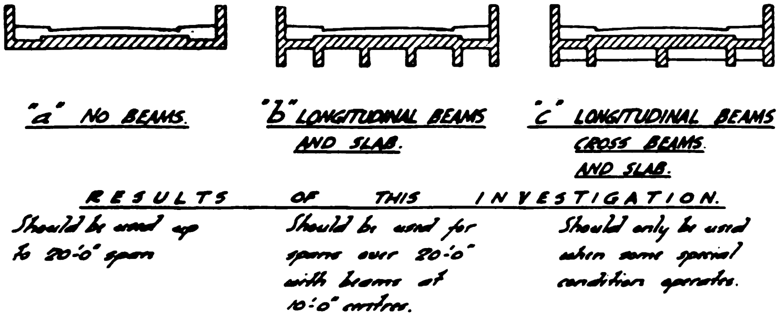

"a" NO BEAMS.
"b" LONGITUDINAL BEAMS AND SLAB.
"c" LONGITUDINAL BEAMS CROSS BEAMS AND SLAB.
RESULTS OF THIS INVESTIGATION.
Should be used up to 20-0" span
Should be used for spans over 20-0" with beams at 10-0" centres.
Should only be used when some special condition operates.

Fig. 1. Possible Constructions for Small Bridges.

The standardising of loading by the Ministry of Transport makes it useful to investigate its influence on these variables in design so that definite rules, or rather ideas, may be framed which will point the path to economic design.

Take a simple span of 20 ft. for a 40-ft. roadway. It can either be spanned by a simple solid slab without beams, or it can have beams at 5 ft., 8 ft., 10 ft. —13 ft. 6 in. centres carrying the road slab—and then should there be intermediate beams between such longitudinal beams ? *Fig.* 1 shows the various solutions. Which one is the most economical and the simplest to construct ?

The purpose of this investigation is to answer such questions for Ministry of Transport loading. The Ministry of Transport loading is given in *Fig.* 2.

Consider generally the case with longitudinal beams carrying a slab.

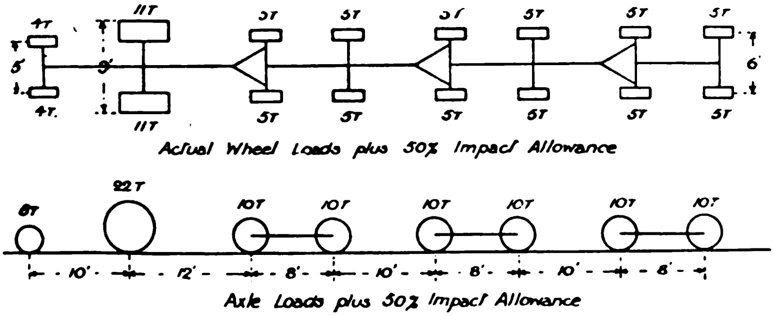


Fig. 2.—Ministry of Transport Standard Loading.

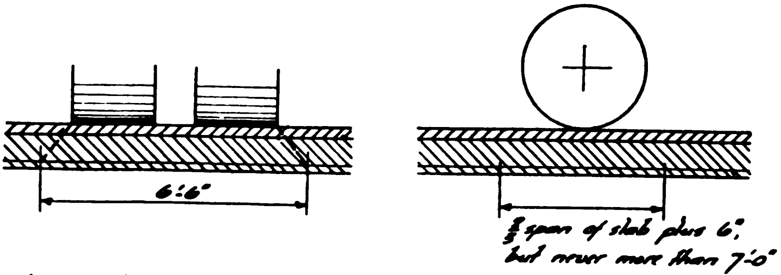


Fig. 3.—Assumptions for Distribution of Point Loads for Slab Spanning across Bridge, i.e. carried on Longitudinal Beams.

The important factor in designing a slab is the distribution therein of the influence of the point load. *Fig.* 3 shows the assumption made for the distribution of the point load in slabs spanning in the direction of the width of the road.

Dead load is assumed to be the weight of the concrete plus 3 in. of surfacing. If surfacing is actually greater the results are not much affected, as the increase in the dead load is offset by the diminished effect of the point loads, due to better distribution over a greater area of slab through the thicker surfacing. Concrete is assumed to be 3 : 1½ : 1, with an allowable fibre stress of 850 lbs. per sq. in., and steel 16,000 lbs. per sq. in. in safe tensile resistance.

Working on these assumptions on the

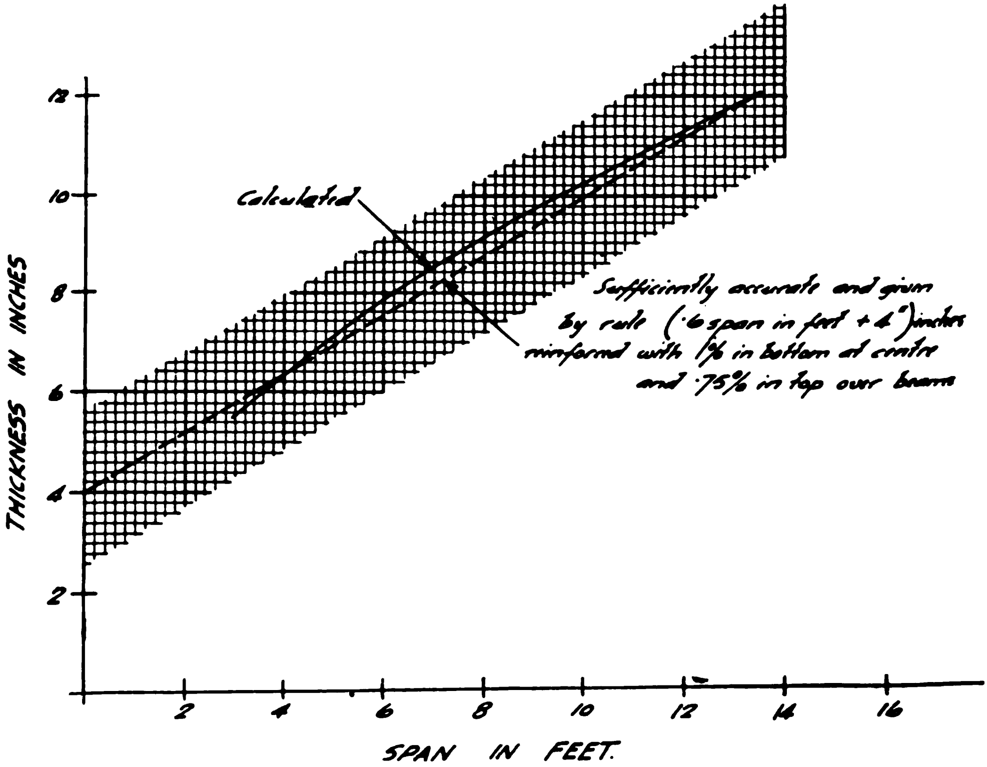


Fig. 4.—Slabs Spanning across Bridge, i.e. carried on Longitudinal Beams.

well-known methods of calculations, *Table* 1 is obtained giving slab thickness for various spans.

TABLE 1.—SLAB SPANNING ACROSS BRIDGE (*i.e.*, CARRIED ON LONGITUDINAL BEAMS AS IN FIGURE 1 " b ").

Span of Slab.	Thickness in Inches.
ft. in.	
3 0	5½
5 0	7
7 0	8¼
10 0	10
13 6	12

The graph of *Fig.* 4 has been plotted from these results and a straight line law deduced giving the following rule for the thickness of this class of slab :—

S = span of slab in feet.

The thickness of slab in inches

$$= \cdot 6\, S + 4 \text{ in.}$$

It is now necessary to compute the cost of this slab. Unit prices of materials assumed are :—

Concrete, £3 per yard cube.
Steel, £20 per ton.
Centering, 7*s.* 6*d.* per yard super.

From these prices and the previous rule the cost of a slab of this type of any span can be found to be $\left(\frac{\text{span}}{6} + 2\right)$ shillings per sq. ft.

Calculations have now to be made to estimate the cost of the longitudinal beams, and the results of these calculations for various spans and spacing of beams are given in *Table* 2, the costs being on the basis of a square foot of bridge area.

The cost of longitudinal beams has then to be added to the cost of the slab appropriate to the spacing of beams, and is shown in *Table* 3. This gives the cost of any combination of beam and slab system, and is plotted as graphs in *Fig.* 5.

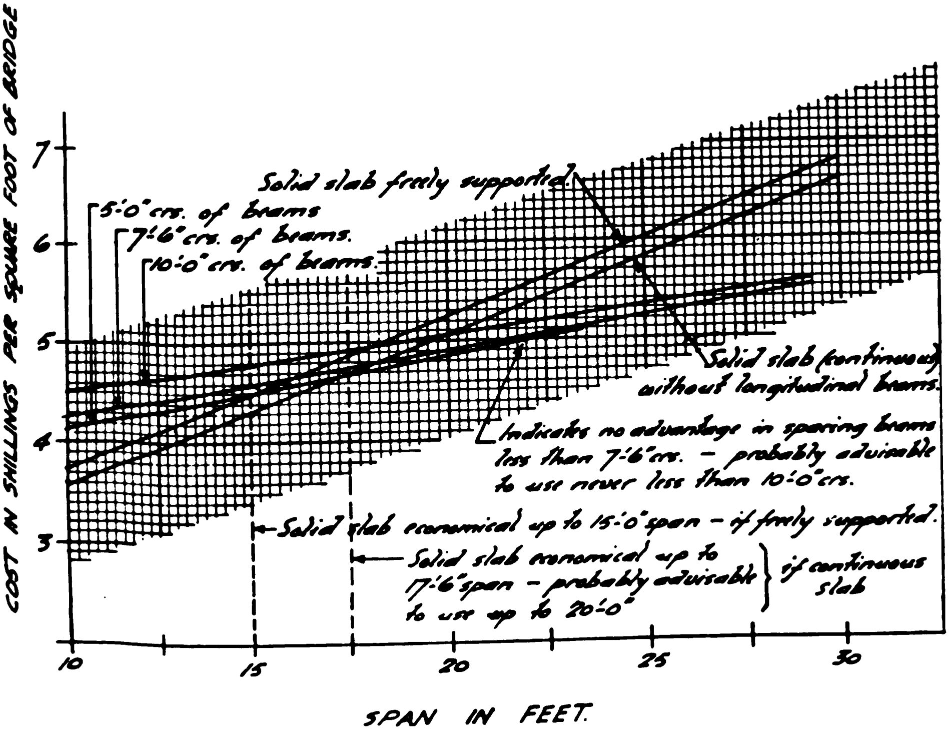


Fig. 5.—Comparison of Costs : Slab and Beams (with various spacings of beam) *versus* Solid Slab.

TABLE 2.—LONGITUDINAL BEAMS.

Cost per Square Foot of Bridge Area in Shillings.

Span of Beams.	Spacing of Beams.			
	5 ft.	7 ft. 6 in.	10 ft.	15 ft.
10 ft.	1·30	1·00	·85	—
15 ft.	1·65	1·30	1·10	—
20 ft.	1·90	1·55	1·40	—
40 ft.	—	3·35	3·00	2·75

TABLE 3.—SUMMARY TOTAL COST IN SHILLINGS PER SQUARE FOOT OF BRIDGE AREA.

Cost of Slab and Longitudinal Beams.

Span of Bridge.	Centres of Beams.			
	5 ft.	7 ft. 6 in.	10 ft.	15 ft.
10 ft.	4·13	4·25	4·51	—
15 ft.	4·48	4·55	4·76	—
20 ft.	4·73	4·80	5·06	—
40 ft.	—	6·00	6·66	7·25

Cost of Solid Slab with No Beams.

Span of Bridge.	Continuous.	Freely Supported.
10 ft.	3·60	3·75
15 ft.	4·35	4·5
20 ft.	5·05	5·3
30 ft.	6·70	—

The alternative solid slab has now to be computed for various spans—this slab spanning in the direction of the road and for which the distribution of the point loads is rather different from that for the previously considered slab. The distribution assumed is shown in *Fig.* 6.

Calculated on these assumptions *Table* 4 gives thicknesses of this type of slab for various spans both when continuous and freely supported.

These results have been plotted in *Fig.* 7, and straight line laws deduced being

For continuous slabs

(·5 span in feet + 4½ in.) inches.

For freely supported slabs

(·6 span in feet + 5 in.) inches.

The corresponding costs being

For continuous slabs

$$\left(\frac{\text{span}}{7} + 2{\cdot}2\right) \text{ shillings per square foot.}$$

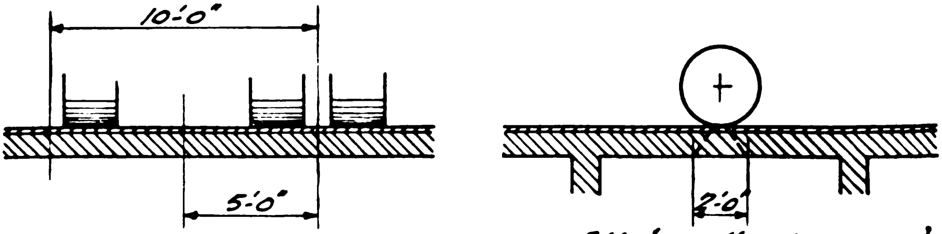
For freely supported slabs

$$\left(\frac{\text{span}}{6{\cdot}5} + 2{\cdot}2\right) \text{ shillings per square foot.}$$

TABLE 4.—SLAB SPANNING IN DIRECTION OF BRIDGE, *i.e.* NO LONGITUDINAL BEAMS, AS IN FIGURE 1 "a."

Span of Slab.	Thickness of Slab in Inches.	
	Continuous Slab. Inches.	Freely Supported Slab. Inches.
5 ft.	6½	7¾
7 ft. 6 in.	8	9½
10 ft.	9½	11
15 ft.	12	14
20 ft.	14	17
30 ft.	20	25

Table 3 gives the cost of this type of slab for various typical spans, and these have been plotted in the graph shown in *Fig.* 5.



Effect of this is equivalent to taking span 1'-0" less than actual

Fig. 6.—Assumed Distribution of Point Loads for Slabs Spanning with Bridge, i.e. no Longitudinal Beams.

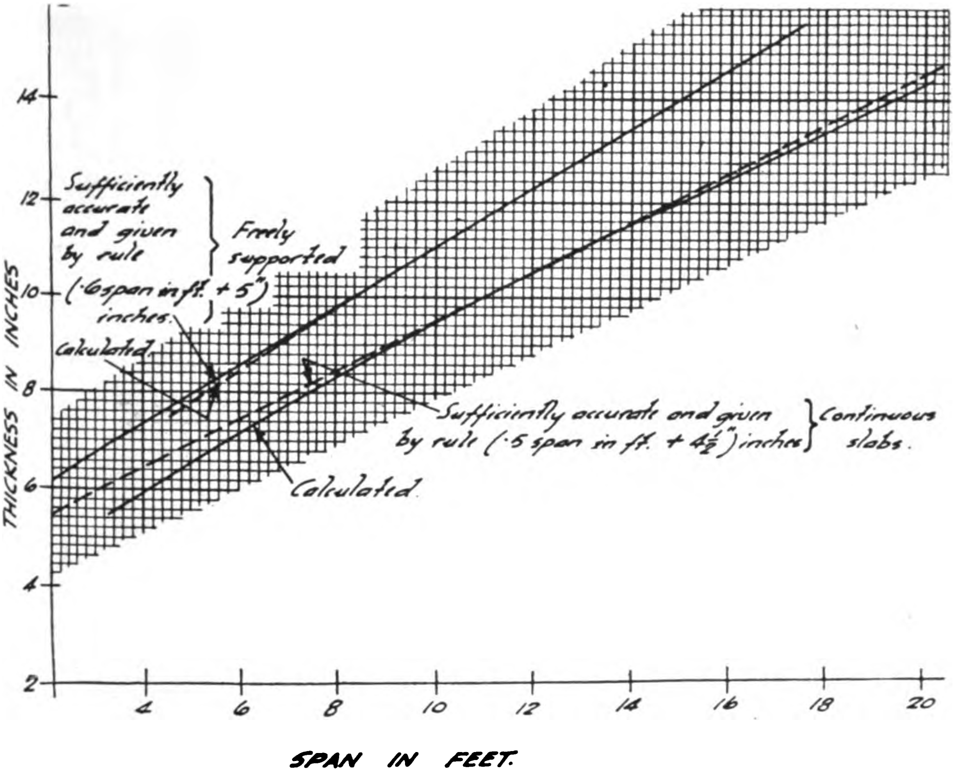


Fig. 7.—Slabs Spanning in Direction of Bridge, i.e. no Longitudinal Beams.

Important deductions can be made from these graphs, being :—

(1) Solid slab bridge up to 15 ft. to 20 ft. span is more economical than longitudinal beams and slabs, and is simpler to construct.

(2) It follows that no bridge under 20 ft. span should have longitudinal beams.

(3) It follows that slab thicknesses up to 14 in. are economical.

(4) No appreciable economy is effected by closer spacing of longitudinal beams than 7 ft. 6 in., and very little extra cost is involved if spaced at 10 ft., but simplicity of construction is much improved.

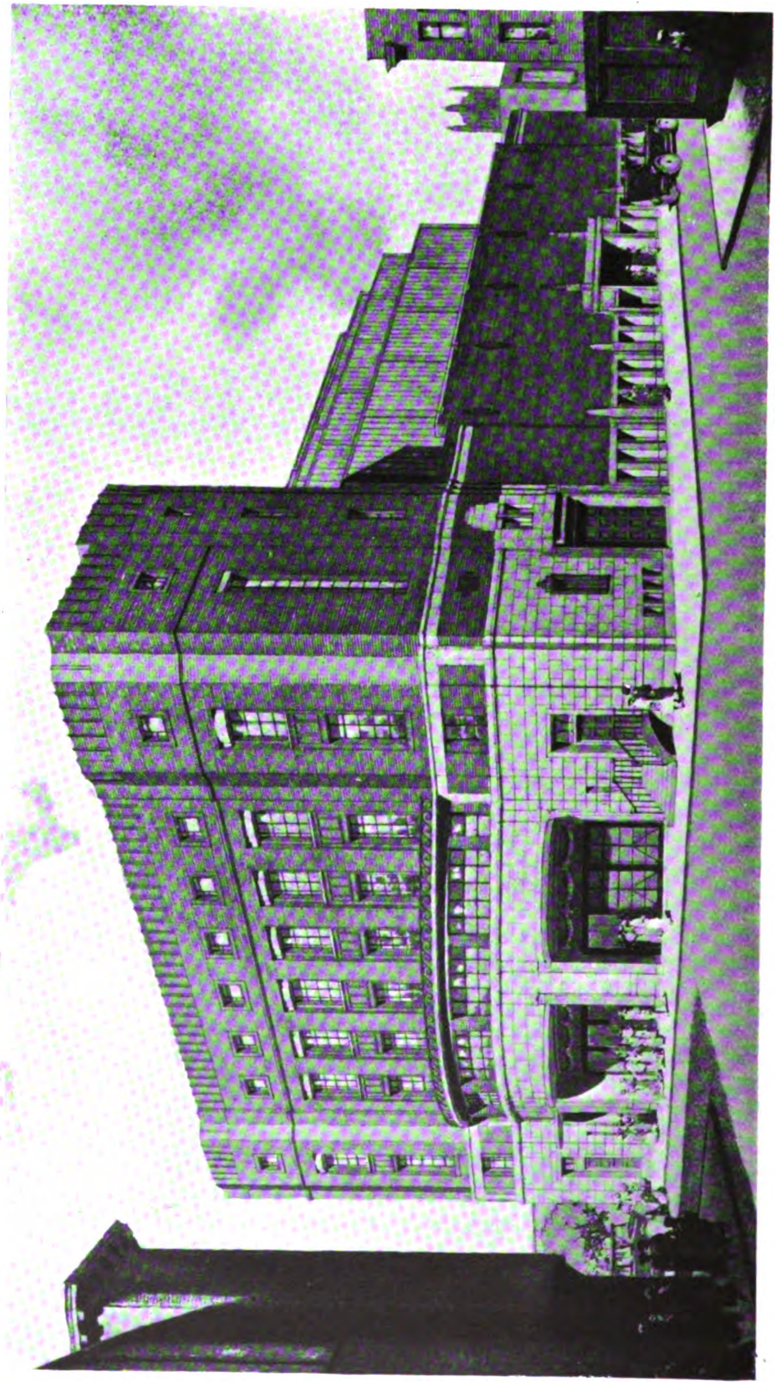
(5) A spacing of longitudinal beams at 10 ft. centres results in slab thickness of 10 in., from which it follows in conjunction with (3) that slabs in bridges can economically be not less than 10 in. nor more than 14 in. thick—substantial thicknesses very desirable for bridges.

(6) As longitudinal beams would not economically be spaced more than 20 ft. apart, it follows from (1) that cross beams between longitudinal beams are never desirable, and, being a complication, should be avoided.

Returning to *Fig.* 1, the deductions made from this investigation are seen at a glance.

It is not pretended that these conclusions apply to all conditions of design. The economic span of solid slab construction can under certain conditions be extended far beyond 20 ft. The author has found that for 60-ft. span road bridges over four railway tracks where the decking and abutments can be made to act as a frame solid slab construction both for abutments and decking is economical, although a thickness of solid slab of 3 ft. is necessary.

There is, however, one fact which this investigation conveys, and that is that no beam of less than 20 ft. span should ever be used in highway bridges for Ministry of Transport loading.



[Messrs. Easton & Robertson, Architects.

The New Royal Horticultural Hall, Westminster: Accepted Design. (*See page 365.*)

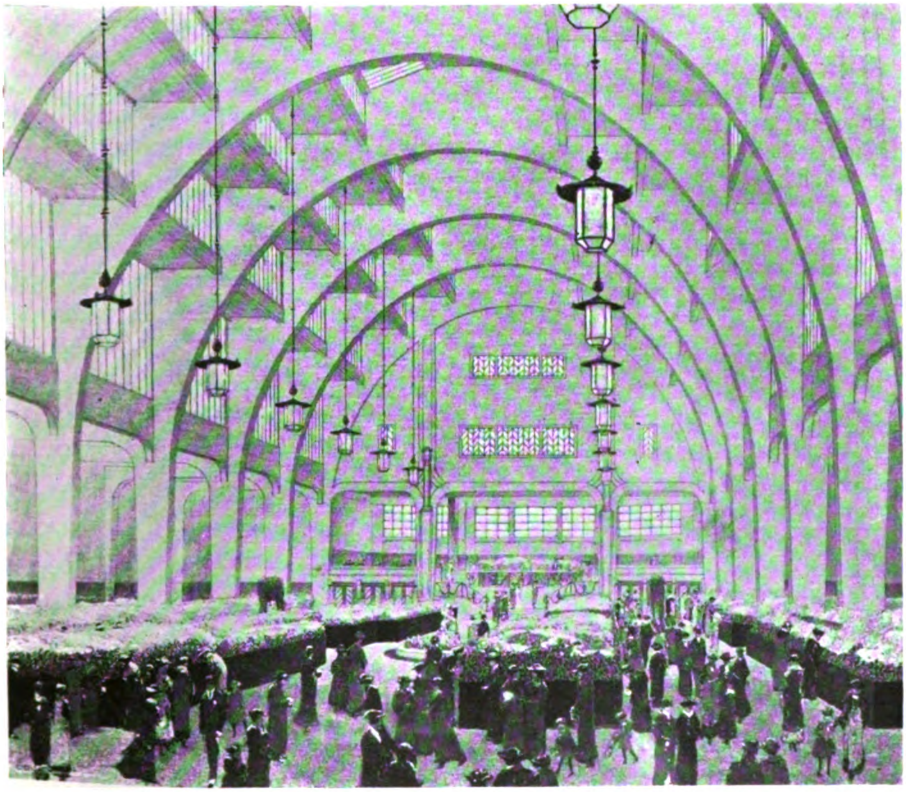
The New Royal Horticultural Hall.

A REINFORCED CONCRETE DESIGN.

THE illustrations on pp. 364 to 368 show the design for the new Royal Horticultural Hall, Westminster, prepared by Messrs. Easton & Robertson, the architects, and accepted in a recent competition.

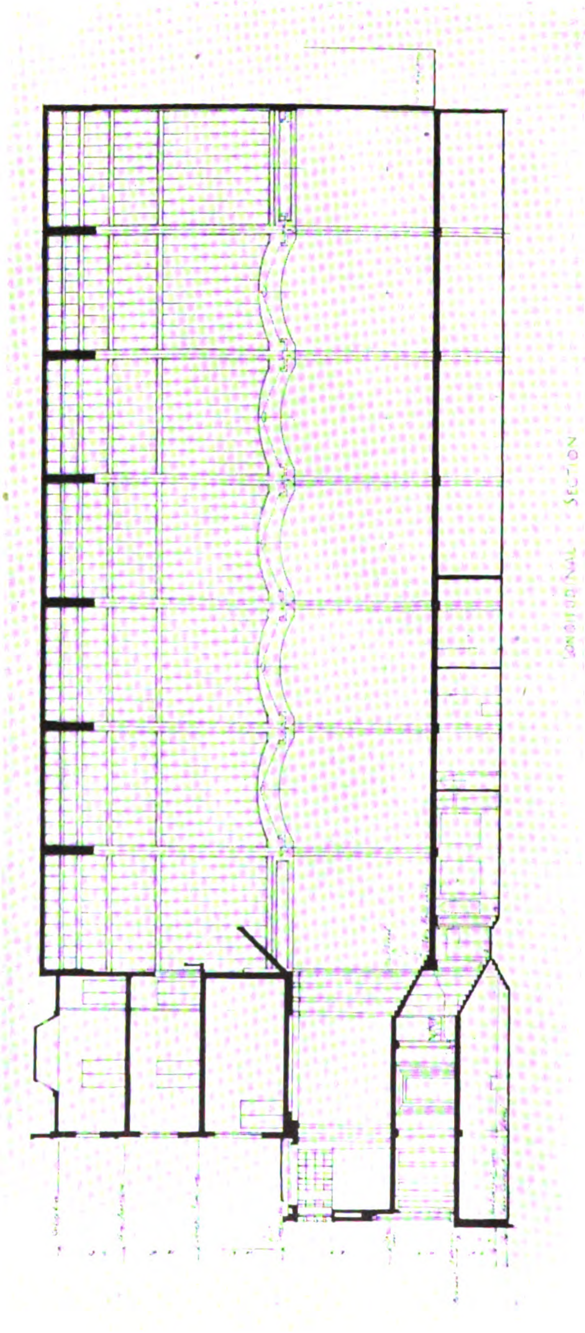
The main feature of the design is the interesting cross-section showing the arches and the various clerestory glazing based on some buildings in Sweden, and which give uniform and excellent light on the exhibition floor. The design and architectural features, which are particularly interesting, reflect great credit on the architects for their treatment of the scheme. The reinforced concrete work is being designed by Dr. Oscar Faber, O.B.E., D.Sc., M.Inst.C.E.

In this issue we give some of the principal architectural drawings, and the reinforced concrete work will be fully described and illustrated in a future issue when the work is more advanced.



INTERIOR VIEW.

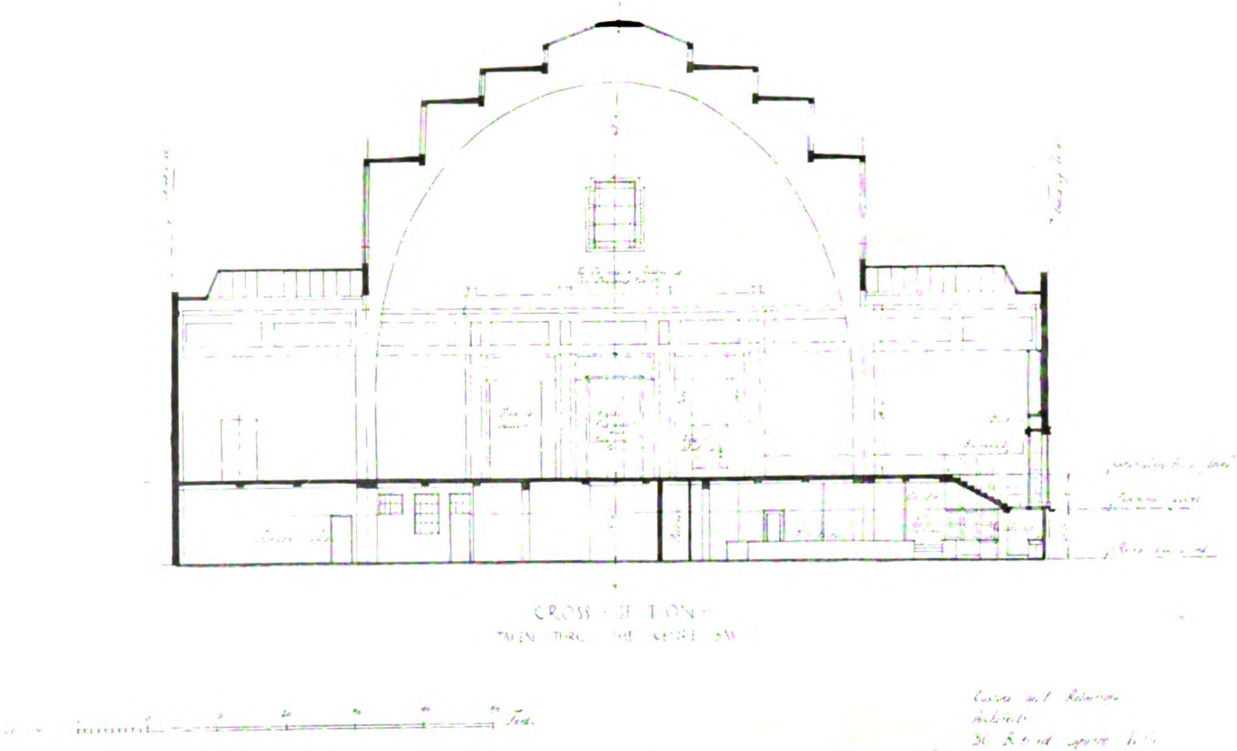
New Royal Horticultural Hall.



[Messrs. Easton & Robertson, Architects.

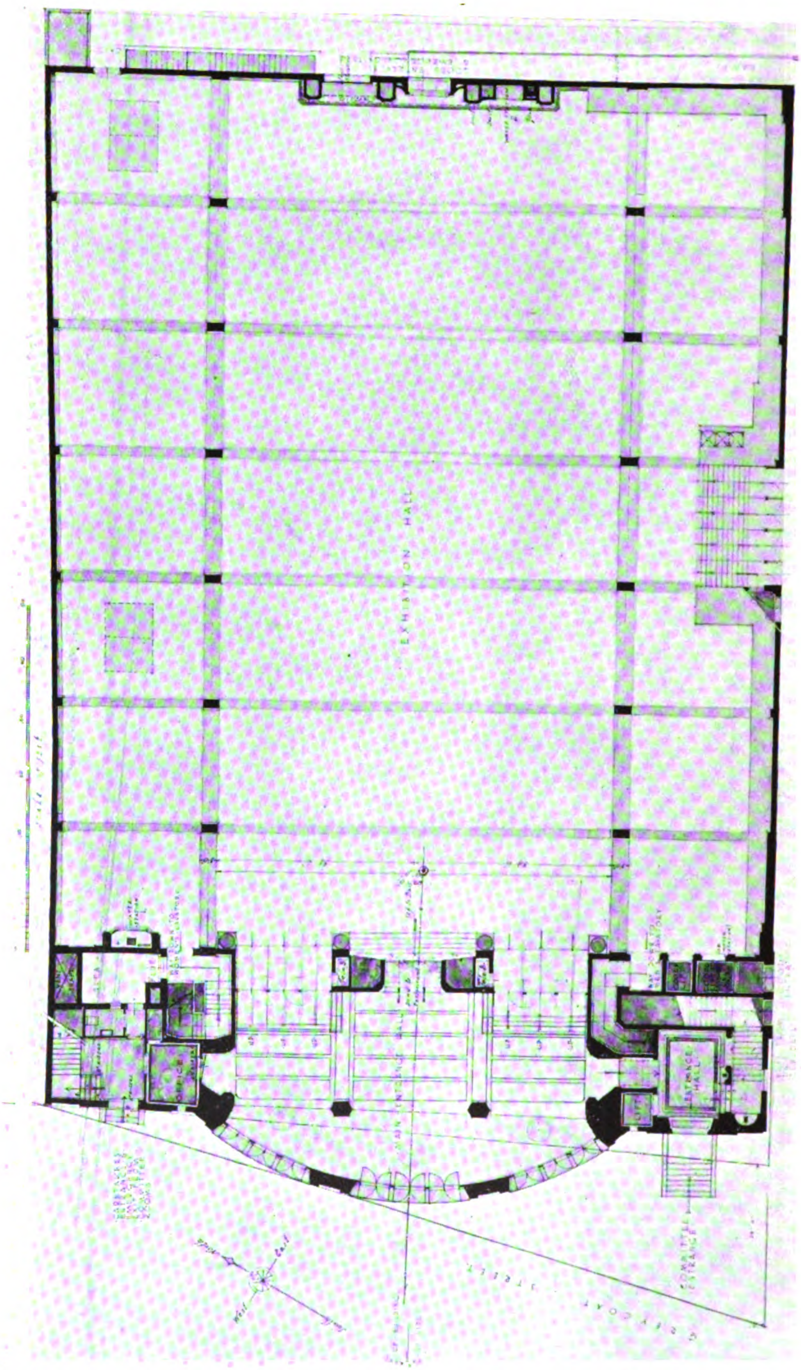
LONGITUDINAL SECTION.

Design for New Royal Horticultural Hall. (*See p.* 365.)



CROSS SECTION.

Design for New Royal Horticultural Hall. (*See p.* 365.)



[Messrs. Easton & Robertson, Architects.

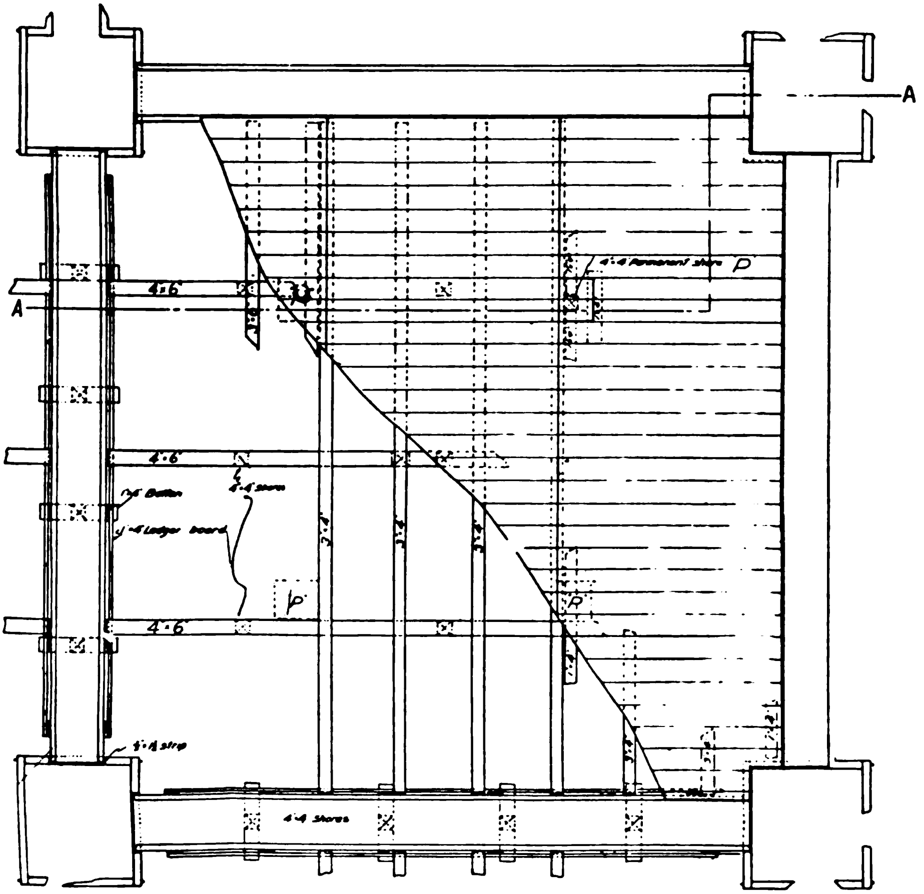
Design for New Royal Horticultural Hall (Ground Plan). *(See p. 365.)*

Stripping Form Panels without Removing Shores.

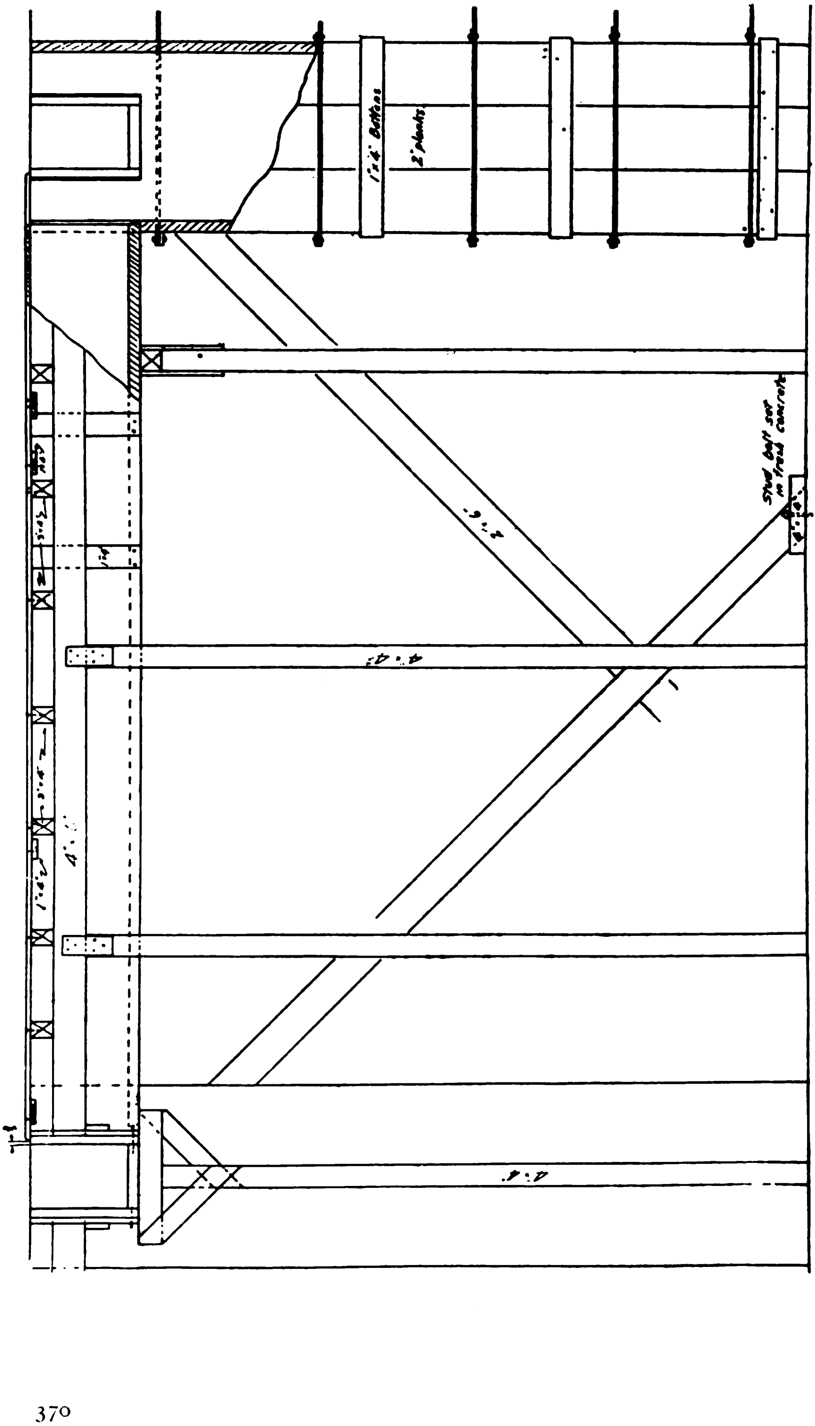
We give herewith two drawings showing the method of formwork adopted on a large new American reinforced concrete building. For the illustrations and the following description we are indebted to an article by Mr. C. H. Schwertner, of the Turner Construction Company, in our contemporary *Concrete*.

The building is of reinforced concrete construction throughout, having floors consisting of large rectangular bays with beams between columns only. As it was necessary that the best possible surfaces be obtained on the columns, beams, and ceilings, the question of forms was given very careful consideration.

The column forms were made up of 2-in. dressed planks, 1-in. by 4-in. battens being used to hold together the planks forming each side, and care being exercised not to let any of the nails in the battens project through the forms where they would show in the finished concrete surface. The beam openings in the columns were made to the exact depth of the beam form and 1 in. wider. The separate sides were nailed together with double-headed nails to permit easy stripping. After the forms were assembled and erected steel column clamps were used to hold the forms together while concreting and until the concrete had



Plan of one Bay: Permanent Shores Indicated by "P."



Section A-A

Elevation of one Bay.

finally set and hardened sufficiently to permit their removal.

The beam forms consisted of 2-in. bottoms and 1¼-in. sides made up with 1-in. by 4-in. vertical battens. To these battens 1-in. by 4-in. horizontal ledger boards were fastened to support the floor panel system. Vertical ½-in. by 1½-in. strips were nailed to the ends of the beam sides to make up the difference between the cut in the column form and the beam form width. The function of this strip is to provide clearance between the beam side and the column form when the column form is removed with the beam still in place.

The floor panels, of which there were three to each bay, were made up of ⅞-in. dressed and matched lumber nailed securely to 3-in. by 4-in. joists. These panels were made 1 in. short of the distance between the inside beam faces so as to permit easy removal of the panels.

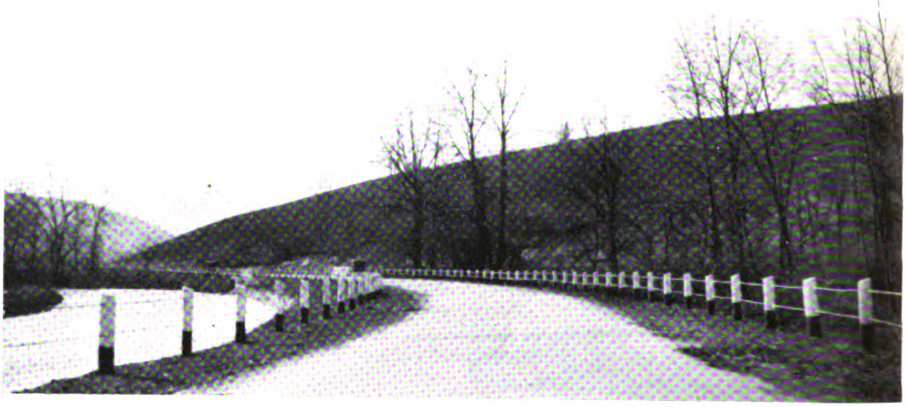
The column forms were first erected to the exact height with respect to the floor above, and securely held in position by means of 2-in. by 6-in. braces running diagonally from the upper portion of the column to a block fastened to the floor. The manner in which this block is fastened to the floor is shown in the sketch. The beam forms were next hoisted into place. It was found that the beam could be held by driving one nail through the beam bottom into the column form. No wedging or keying was necessary for the smaller beams, while only a piece of 2-in. by 4-in. timber nailed to the beam side to prevent the column from spreading was necessary for the larger beams. Shores were then installed under the beam forms. The 4-in. by 6-in. timbers, cut to exact length, were then laid on the ledger boards as shown in the sketch, after which the floor panels were laid down. It was found that these panels could be easily held by driving a few small nails through the panels into the beam sides. Shores were then erected under the 4-in. by 6-in. timbers.

Since floor forms as have been described are relatively expensive to build, it was found necessary to devise means to quickly remove and re-use them without inducing dangerous stresses in the concrete. To accomplish this a system of permanent shoring was decided upon which would permit the early removal of the floor panels. This system consisted of providing four shores in each bay which remained in place together with a small piece of panel while the balance of the panel was being removed. These shores are referred to as " P " in the accompanying sketch. As the sides only of the beams were removed before 28 days no difficulty was experienced in providing support under them.

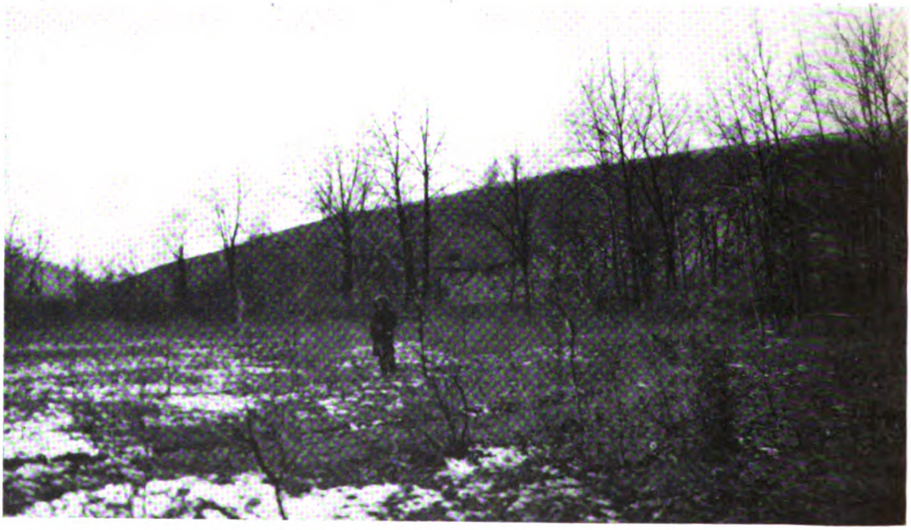
The column forms were first removed. This was made very easy with the beams in place because of the clearance provided by the ½-in. by 1½-in. strip. Beam sides were next taken down, after which the floor panels were dropped into ropes in order to prevent damage to them as much as possible.

It was found to be an easy matter to reduce column forms to proper size when moving them up to higher stories. To facilitate this a small portable electric handsaw was used, and made it easy for the carpenter to rip off the material required to be removed, since this saw operated quickly and called for a minimum of muscular exertion.

Particular advantages of this system of form construction are the small amount of skilled labour required to erect the floor forms once the columns are erected, the ease with which the column forms can be removed with the beams still in place, and the system of permanent shoring which permits the early removal of the floor forms without unduly stressing the concrete and without the necessity of reshoring.



View in December, 1924, after Construction in Reinforced Concrete.



The Site in March, 1924.

Another View of Route 12, Before and After Reconstruction.

CONCRETE HIGHWAY CONSTRUCTION IN THE U.S.A.
(*See p.* 373.)

Concrete Highway Construction in the U.S.A.

By W. L. BRAYBROOKE, B.Sc. (Lond.),
(*Resident Engineer, New Jersey State Highway Department.*)

For nearly a century subsequent to the days of Telford and Macadam little interest was taken in the science of highway engineering. The railway had ousted the stage coach, and highways were of little importance when compared with the railway. Thus the methods and materials of road construction remained practically unchanged from the beginning of the nineteenth century until its close. But the advent of the automobile and the enormous volume of motor vehicle traffic that quickly followed caused an awakening of interest in the highways. Engineers soon discovered that the new type of traffic required an almost totally new type of road. Many experiments were carried out, and highway engineering began to be regarded as an important branch of civil engineering. (In several American colleges there are now chairs in Highway Engineering.)

The highway problem, although affecting most civilised countries, has been felt most acutely in the United States. There are at present 18,000,000 motor vehicles on the roads of this country, or enough easily to transport the entire population at the same time. This number—large as it may seem—is increasing at a rate of about 14 per cent. per annum. In Europe the highways preceded the railways, but over a large area of the U.S.A. the railways were the pioneers, and consequently the highways were few and not very good. There sprang up an imperative demand for good highways and most of the States are engaged in carrying out elaborate programmes of road construction, with the Federal Government contributing to some extent. For example, New Jersey has a road programme which calls for the expenditure of 80,000,000 dollars in five years.

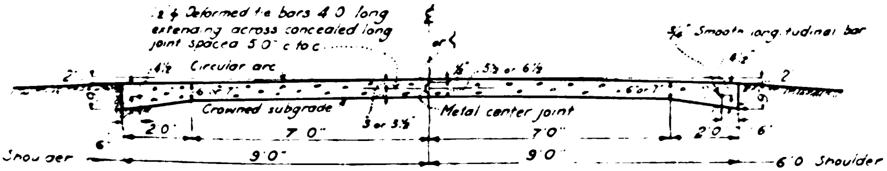
The majority of the State Highway Departments have come to the conclusion that a concrete road is the best for general automobile traffic—especially for rural highways—when all the factors (strength, surface, wear, cost, etc.) are taken into consideration. The first cost ranks high (about 75,000 dollars per mile in New Jersey), but the cost of maintenance is practically negligible for a considerable number of years. To give some idea of the extent to which concrete is used, the following figures are given, representing the contracts awarded from January to November, 1925:

	Square Yards.
Roads	61,403,831
Streets	34,083,713
Alleys	3,337,993
Total	99,825,537

The cost of this work is in the neighbourhood of 250,000,000 dollars.

The immense amount of concrete construction entailed by all these road programmes has called into being a demand for more light on the subject of concrete. A large amount of experimental work has been carried out already, and is continuing. The U.S. Bureau of Public Roads has carried out elaborate tests with road sections of various design, and the Illinois State Highway Department has, from its Bates Test Road, evolved an "ideal" section (shown in sketch).

Notable work has been done by Professor D. A. Abrams in a laboratory maintained jointly by co-operation of the Lewis Institute of Chicago and the Portland Cement Association. It has been



STANDARD SECTION - ILLINOIS

The Macadam Road in March, 1924.

The Same Road in Concrete, December 1924, showing the New Channel of the River.

Views of Route 12, Before and After Reconstruction.

found that the strength of concrete is controlled by the "water-cement" ratio. The less the amount of water used—provided the mix is workable—the stronger the resulting concrete. Care in grading the aggregate results in economy. The old idea of the ratio of fine to coarse aggregate being 1 : 2 is rapidly disappearing, and proportioning by weight instead of by volume, inundation of the sand to obviate the error due to "bulking," are some of the recent developments resulting from the experimental work. It is also proposed to specify concrete by strength alone, regardless of the proportions of the mix.

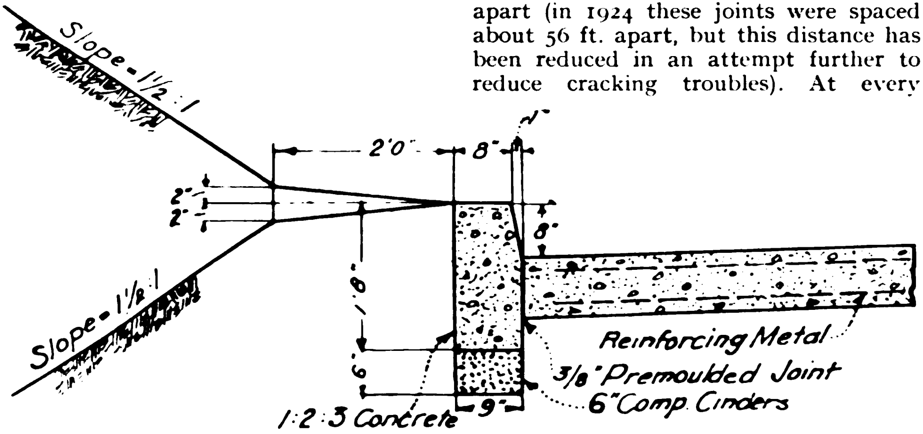
The writer is most familiar with the methods of construction used in New Jersey, but except as regards the type of section these may be taken as fairly typical of present practice in the States.

Usually a road of sorts exists over the line of the proposed highway. A careful survey is made to discover how grades and alignment can be improved. In one job with which the writer was associated a 60-ft. river was "moved" 300 ft. in order that a curve on the highway might be flattened. Details of grades, cross sections, etc., differ only in minor degree from English practice.

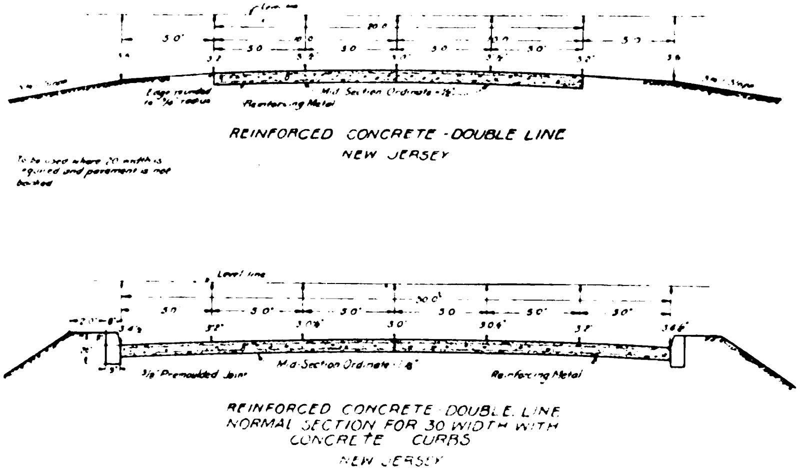
The first concrete road laid by the State of New Jersey was constructed in 1912. No reinforcement was used, but the section was rather thick compared with present-day practice. Although much cracked, this stretch of pavement (forming a portion of one of the main highways) is still standing up well and presents a good riding surface. Maintenance has consisted only in filling the cracks with a bituminous filler.

The section at present used is illustrated. The slab is 8 in. thick, 20 ft. wide on grades up to 4 per cent., and 30 ft. wide on steeper grades. The mix used (1924–25) is 1 : 1¾ : 3½, this being based on an approved grading of the aggregate to give a cement content of 6·40 bags per cubic yard of concrete. The slab is reinforced by a double mat system of ⅜-in. deformed bars. These mats are made 12 ft. long by 9 ft. 6 ins. wide (for the 10-ft. half-width of pavement), the two planes of bars being held 4 in. apart by separators. Adjacent mats are lapped 12 in. In construction a 2 in. layer of concrete is poured and spread, then the reinforcement mat is placed, and the remaining concrete is poured and tamped around and above the mat.

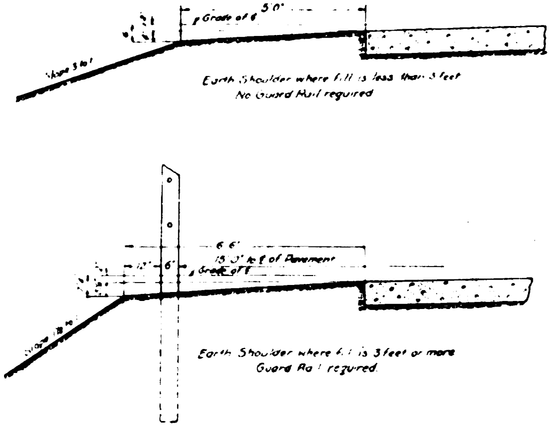
The road is constructed half widths at a time, with the trucks, etc., operating on the other half-width. The half-widths are separated by a bituminous joint, either pre-moulded or poured. Transverse expansion joints are placed at every fourth mat, i.e. about 44 ft. apart (in 1924 these joints were spaced about 56 ft. apart, but this distance has been reduced in an attempt further to reduce cracking troubles). At every



SECTION ON STEEP GRADE IN CUT AND ON FILLS WHERE NO GUARD RAIL IS REQUIRED

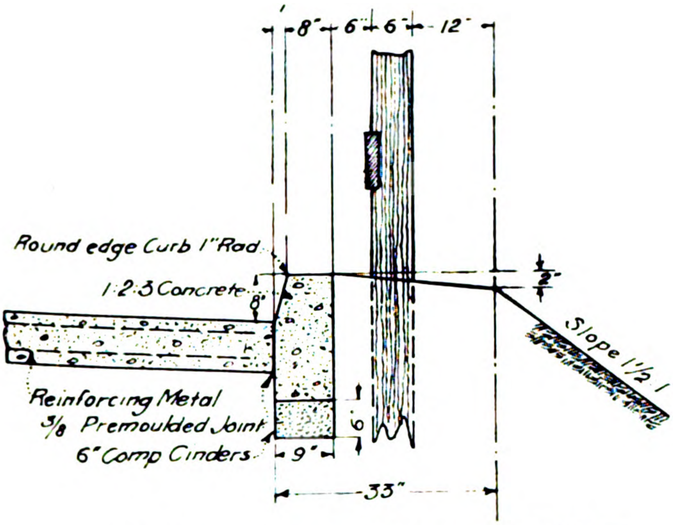


TYPICAL SECTIONS.



SHOULDERS.

Reinforced Concrete Road Construction in the United States.



SECTION ON STEEP GRADE ON FILL WHERE GUARD RAIL IS REQUIRED

transverse joint ⅝-in. dowel pins, 30 in. long, are introduced. Half of each dowel-pin length is wrapped with tar-paper to allow movement in one slab while the other half is firmly embedded in the adjacent slab.

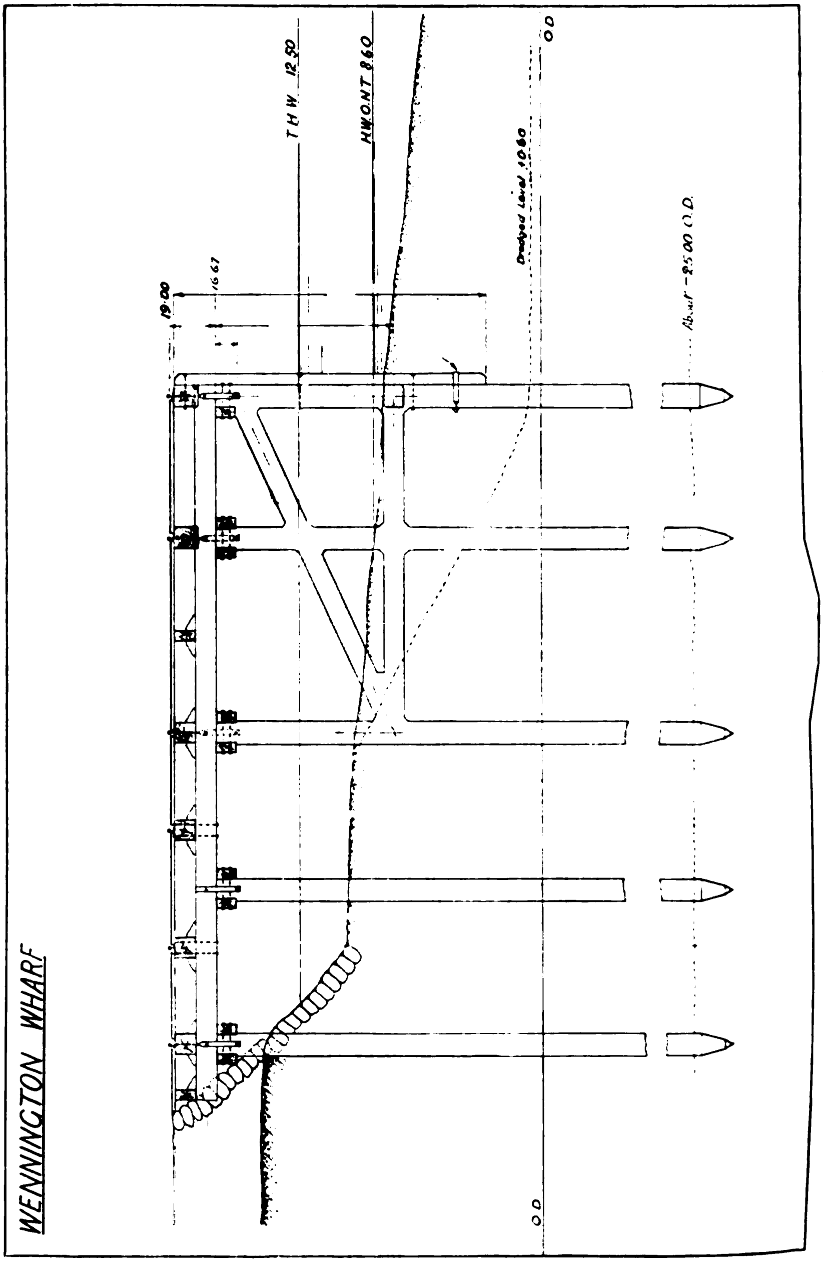
Reinforcement is not used so much for strength purposes (research work is at present being carried on to obtain information on the exact effect of reinforcement on the strength of concrete pavements) but to prevent cracks from growing. These cracks, although unsightly, do not affect the riding qualities of concrete roads. Various causes (temperature changes, inequalities in subgrade, concentration of load, etc.) contribute to their formation, and various attempts have been made to eliminate them, or at least to reduce the number. The most recent experiment is being made in North Carolina, where a transverse plane of weakness is introduced in each slab during construction in the hope of controlling the transverse cracking.

In the matter of finishing the concrete road there is some variance in practice. Previous to 1925 the standard practice in New Jersey was as follows:

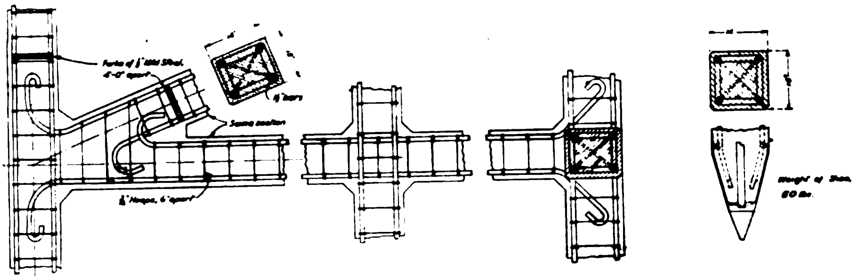
(1) Striking off with a tamping board weighing 8–10 lbs. per lineal foot; followed by
(2) Tamping with a lighter board (4–5 lbs. per lineal foot); and
(3) Three applications of a belt 8 in. in width, with hand-floating to give the final touches to the surface.

In 1925, however, a heavy screed-board has taken the place of the second tamping. This board is 8 in. by 8 in. in section, weighs 20 lbs. per foot, and is used with a sawing motion to smooth the surface. This is followed by belting, and then a "broomed" finish obtained with ordinary street brooms. Machine-finishing is often substituted for hand-finishing, and machines are now on the market which tamp, screed, and belt. The allowable departure from a plane surface as shown by a straight-edge is generally ¼ in. in 10 ft.

After finishing, the surface is protected with wetted strips of burlap or canvas until the concrete is sufficiently set to bear straw. Then a 6 in. layer of straw or salt hay is placed and kept constantly wetted (except in freezing weather) for at least 10 days. In no case is traffic allowed on the new road until 14 days after placing. In exceptional cases (in front of fire-stations, etc.) aluminous cement is used.



Wennington Wharf, Purfleet : Cross Section. (*See p.* 379.)

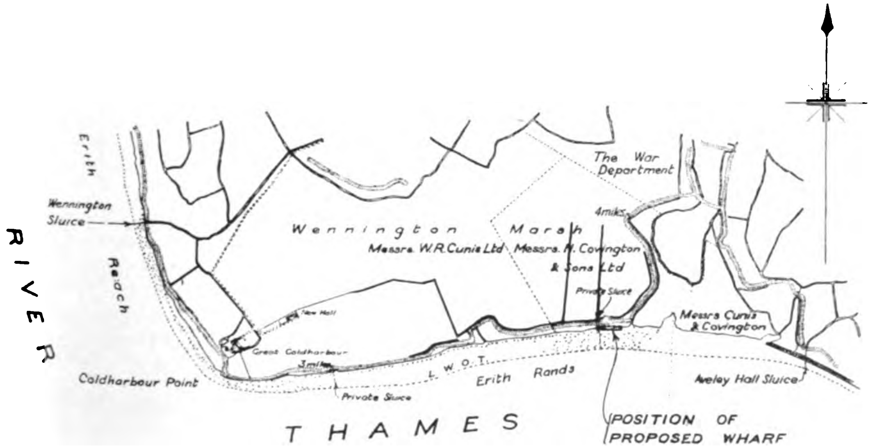


Details of Reinforced Concrete Framing and Piles.

REINFORCED CONCRETE WHARF ON THE THAMES.

Reinforced Concrete Wharf Substructure.

We illustrate herewith a new wharf now being built at Wennington on the Thames opposite Erith, for Messrs. Covington & Sons, Ltd., to the design of Messrs. Case & Cunningham, MM.Inst.C.E., of Broad Sanctuary Chambers, Westminster. The structure consists of reinforced concrete piles and bracing with a timber decking, and measures 300 ft. long by 37 ft. 5 in. wide. It carries a 7-ft. gauge crane-track along the front for an installation of 3-ton cranes, and two tracks of ordinary 4 ft. 8½ in. gauge railway lines. The piles are 14 in. square in section, and have an average length of 40 to 45 ft. over all, about 25 ft. of which is below Ordnance Datum. Altogether, there are 163 piles, spaced 10 ft. apart longitudinally, and in depth according to the tracks.



Site Plan.

The longitudinal bearers and cross bearers and decking are of timber, as also is the fendering. It is proposed to dredge the foreshore down to O.D. level or thereabouts in order to provide berths for barges, and so as to give a depth of water of 12 ft. at Trinity high water. At the north-east corner of the wharf, a water tank and tower are to be provided, carried on special piles.

A feature of the work is the use of "Ferrocrete" rapid-hardening Portland Cement to expedite construction, the piles being driven seven or eight days after casting. The contractors are Messrs. John Shelbourne & Co.

Wearing Properties of Concrete Surfaces.

An exhaustive series of tests on the wearing properties of different types of concrete pavements has been carried out by Messrs. F. H. Jackson & J. T. Pauls, of the United States Bureau of Public Roads.

In their conclusions they state: On the average 18-ft. concrete road, approximately 10 per cent. of the total traffic moving in both directions passes over a band 6 in. in width at the point of maximum concentration. Therefore, the traffic passing over the test road should be multiplied by at least 10 to obtain the equivalent volume of traffic on an actual pavement.

The comparative resistance of each test section to the surface wear produced by the tyre chains is an indication of the comparative resistance which would be offered by the concrete to wear or disintegration at the edges of exposed joints and cracks under service conditions.

Conditions which cause surface wear, such as steel tyres, tyre chains tracking through snow, etc., are present to such an extent as to make it necessary to give the question of wear consideration in the selection of concrete aggregates.

The authors believe that the data so far secured warrants the following conclusions:

The rate of wear of stone concrete is, in general, not affected by the coarse aggregate provided the coarse aggregate is equal or superior to the mortar matrix in resistance to wear.

Excessive wear will result from the use of very soft stone as coarse aggregate even though used in conjunction with a mortar of satisfactory quality. From the results of these comparative tests, it would appear that stone with a percentage of wear over 7·0 should not be used in the wearing course of concrete roads.

Gravel concrete, in general, is at least as satisfactory from the standpoint of wear as stone concrete.

Gravels consisting essentially of siliceous materials are superior as regards both the amount and uniformity of wear than those containing a preponderance of calcareous fragments.

Gravels consisting of rounded particles are as satisfactory from the standpoint of wear as those consisting either wholly or in part of angular or crushed fragments.

Small amounts of shale occurring in the coarse aggregate will cause both excessive and uneven wear.

Blast-furnace slags should prove satisfactory for use in concrete pavements provided the proportion of light porous slag is so controlled that the weight per cubic foot will be at least 70 lbs. The presence of large amounts of light porous fragments in blast-furnace slag will cause excessive wear. Somewhat better results are secured by the use of the smaller sizes of slag.

Slag or stone screenings are, in general, unsatisfactory as substitutes for natural sand as fine aggregates in concrete road construction.

Copper and lead-smelter slags would make satisfactory aggregates for concrete road construction from the standpoint of wear.

Coarse sands, other things being equal, show greater resistance to wear than fine sands.

Neither the crushing nor the transverse strength of concrete is a measure of its wear-resisting properties.

The addition of hydrated lime in the proportion used in these tests does not affect the wear-resisting properties of concrete.

So far as resistance to wear alone is concerned, increasing the cement content beyond a cement-sand ratio of 1 : 2 does not materially affect the concrete. Leaner mixes, on the other hand, show marked increases in wear.

Other things being equal, either an excessively dry or an excessively wet mix will show less resistance to wear than concrete of medium consistency.

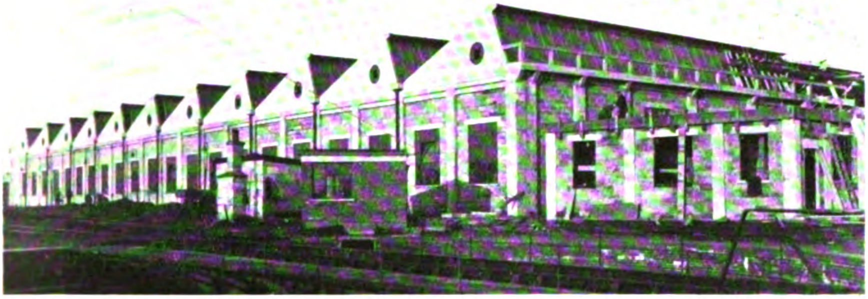


Fig. 1.—Reinforced Concrete Engine Sheds at Exeter.

Reinforced Concrete Engine Sheds.

We give some illustrations of a new reinforced concrete engine shed at Exeter for the Southern Railway, now approaching completion. This work is to the design of the Company's Chief Engineer, Mr. A. W. Szlumper, C.B.E., M.Inst.C.E., the details being supplied by Messrs. L. G. Mouchel & Partners, and the work carried out by Messrs. A. Jackaman & Son, Ltd., of Slough.

A general view of the shed from the south-east is shown in *Fig.* 1. The versatility of reinforced concrete is here well shown in the columns, walls, roof trusses, glazing bars, balustrade, roof hoods, and valley gutters, all of which are in this material; while the long slopes of the north light roofs, only the gable edges of which show, are also of reinforced concrete ribbed slabs. Many of the same features appear in *Fig.* 2, which shows the roof slabs more plainly.

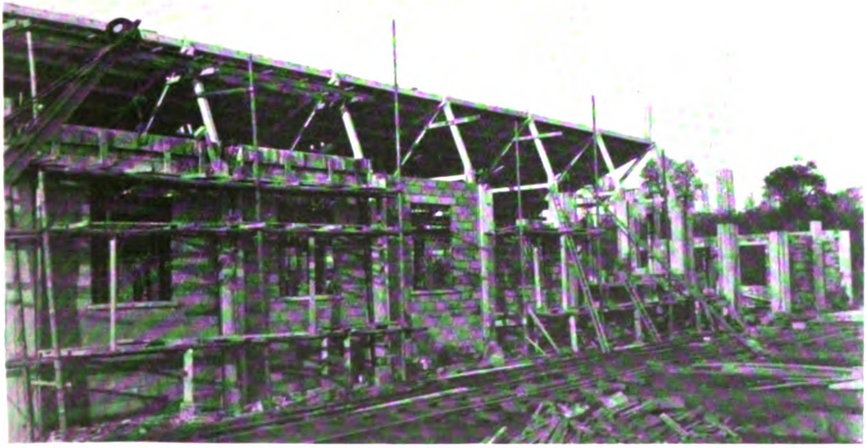


Fig. 2.—Reinforced Concrete Engine Sheds at Exeter.

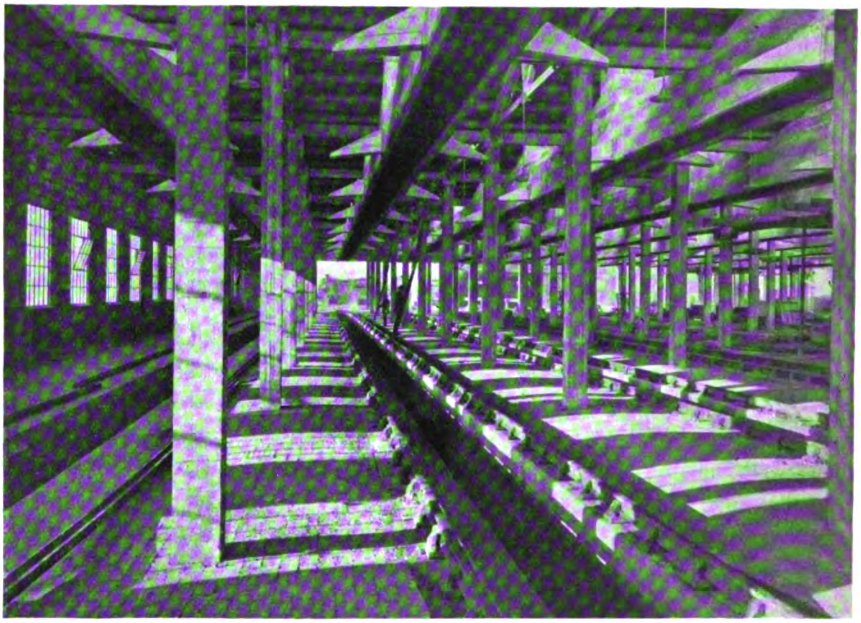


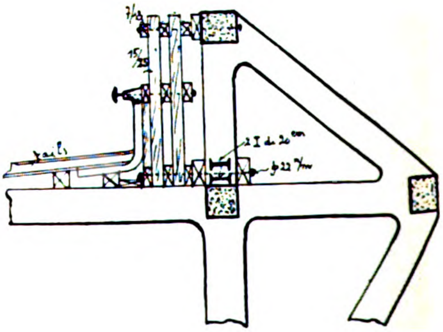
Fig. 3.—Reinforced Concrete Engine Sheds at Exeter.

The resistance to active corrosion in the presence of smoke—which is a feature of properly made concrete—and also the fire-resisting nature of the material are taken novel advantage of in the interior of the shed by the provision of reinforced shoots for smoke and steam from engines standing over the pits. These shoots are light and stiff, and condensation water which would otherwise fall on machinery below is conveyed to the spaces between tracks by means of gutters in the interior of the shoots and spouts at the outlets from these, both of which show clearly in *Fig.* 3.

All the tracks are made with pits underneath and drained. Facilities are provided for repair work by means of an overhead gantry in one bay, whilst the engine shed staff is accommodated along the whole of the north side of the building. The shed covers nearly two acres of ground.

A Reinforced Concrete Buffer-Stop.

The buffer-stop shown in the illustration, as used on the Continent, is a simple design of a semi-elastic nature arranged so as to reduce shock to a minimum. A portion of the shock is absorbed in elastic deformation of the timber blocks, which are bolted to reinforced concrete beams rigidly connected to the top of the trestle.



Notes on Laitance.

At last year's annual congress of the American Concrete Institute Mr. R. M. Miller, formerly Resident Engineer to the Virginian Terminal Railway Co., described a number of investigations he had carried out on the subject of laitance on concrete in the course of some large under-water concrete foundation work.

After fully describing these investigations, he said laitance varied in chemical constituents from those of the cement used on the work no more than one standard brand of cement varied from another. It therefore seemed unlikely that any chemical reaction or crystallisation of importance took place between sea water and the cement of the laitance during the pouring or during the four or five days that the laitance had remained immersed. In his mind the suspicion had lingered that the chemical constituents of sea water were responsible in some measure for excess formation of laitance in under-water concrete. While that suspicion was strengthened, it had been by no means confirmed.

Quite evidently something of importance took place between sea water and the cement of under-water concrete during the first weeks. On account of the conflicting views as to the behaviour of cement in sea water it was not his intention to suggest the addition to the cement of siliceous materials or the use of special cements, but rather improvement through better protecting the plastic mass of concrete from contact with fresh or sea water by more careful methods of placing.

The formation of laitance withdrew from the concrete by wash the fines of the cement. It was extremely doubtful if the concrete placed by bottom drop bucket or " tremie " was so affected throughout its mass. It was highly probable that only the outside of the concrete charge was so affected, and that the resulting concrete consisted of masses of dense concrete between which would be found pockets or layers of concrete of much greater porosity. If the amount of permeability of the concrete was responsible for the rate of disintegration by the action of the salts of sea water, it followed that the presence of layers or pockets of lean concrete or of laitance or construction seams invited failure. It was therefore of the greatest importance that the formation of laitance be kept to a minimum. In the case of the Virginian Railway Pier No. 2 the steel caissons were left in place after completing the foundation, and that was a very effective protection against the action of the sea water.

Whether or not any chemical reaction of importance occurred between salt water and cement in the formation of laitance, the condition of the mix and the wash was in large measure responsible. It was mainly a question of manipulation. Laitance can be held to minimum by the following precautions :

(1) Use a clean aggregate.

(2) Make the bottom as free of mud as possible.

(3) Use fresh water in the mix, free from dirt, earth or sewage.

(4) Cut off all high piles that have driven to refusal. Hold the penetration of the foundation piles into the concrete to a minimum for stability.

(5) Use mix of a uniform consistency.

(6) Leave the bottom drop bucket open at the top but with bottom doors that open freely downward when tripped. Fill the bucket completely with concrete before being slowly lowered. When discharged the bucket should be returned slowly until clear of the concrete. The installation on the bottom of the bucket of an automatic trip so arranged that the bottom drops cannot be released until the trip has touched pile heads or concrete. If metal top doors are to be used they should preferably rest upon the charge of concrete when the bucket is full and open downward and follow the concrete as it is emptied. If the usual top doors resting upon the rim of the bucket are to be used they should be so arranged that they can be opened slowly upward before the charge is emptied.

(7) If the arrangement of the foundation piles and the shape and dimensions of the foundation caisson are such that the " tremie " can be used to advantage it is preferable to the bottom drop bucket, provided the nose of the " tremie " is kept below the surface of the concrete already placed and the pipe is continually

full of concrete. Every charge lost means additional laitance.

Retempering of concrete had also been found of advantage in the elimination of laitance. This process consisted in mixing concrete and storing for several hours during which time the initial set took place. It was then returned to the mixer and remixed without the addition of water. Concrete retempered within two or three hours gained slightly in strength, hardened much more rapidly, would show no shrinkage after being placed in the dry, or swell when poured under water, and would not lose the fines of the cement through wash to any appreciable extent. The time of retempering could be extended to as much as five hours. Retempering of concrete on work of any magnitude was of somewhat doubtful value, as the time lost in storing and remixing was an important factor. The cost of furnishing either the necessary hopper cars and track for three hours' storage or the construction of bins, chutes and an elevator or any other storage device would necessarily be reflected in the unit cost per cubic yard to such an extent as to make the plan on many jobs unacceptable.

The application of corrective measures to the pouring of the under water concrete for the Virginian Railway Pier No. 2 effected a marked improvement. Whereas on the extreme inshore end of the pier the formation of laitance reduced the mix from 1 : 2 : 4 to 1 : 2·8 : 5·6, on the outboard end the resulting mix averaged 1 : 2·2 : 4·4. In short, if laitance developed either in under-water concrete or concrete poured in the dry the cause was too much water either in the mix or added to the concrete in placing.

In a discussion which followed the paper, Mr. Edward Godfrey said the discoveries of Mr. Miller on the formation of laitance on concrete deposited in water, and his recommendations regarding the handling of concrete to avoid or lessen the formation of laitance, were of vital importance. Analyses showing that this substance was identical in composition with the cement and that laitance was not, as they were sometimes told, decomposed cement, were also of interest and importance. It was by recognition of facts such as these that progress in the handling of concrete was made.

Mr. Miller showed by analysis that laitance was identical in composition with cement; that the coarser particles of the best Portland cement were totally inert; and that the laitance, or finest dust of cement, was the only cementing substance present. The laitance, or true cement, was totally useless and hopelessly weak unless mixed into the interstices of some inert substance, such as inert cement particles (too coarse to be true cement) or sand.

Facts demonstrated clearly that the strength of cement was due to its colloidal or glue-like nature, and not to crystallisation. An expert in the chemistry of cement had recently dealt with laitance as though it were merely something of no value—on a par with mud—and the only problem was to get rid of it. The fact that this was the very product that was made by the undoubted improvement of cement manufacture—fine grinding—and represented large capital investment that produced that fineness, did exhibit itself in that expert's paper. The seriousness of the formation of laitance, in any quantity, because of the loss of cement value, and means of preventing its formation, were very important considerations.

It was found that concrete deposited in water might lose 13·2 per cent. of the cement in the laitance, and it was well to use about 10 per cent. extra cement for concrete that was to be placed under water to allow for loss.

Retempering concrete or holding it for any time after mixing were both universally condemned and warned against in all standard literature and specifications, with no suggestion of any beneficial results under any condition. Mr. Miller found that holding for hours and retempering were very beneficial where the concrete was to be deposited in water, and he (the speaker) had repeatedly recommended these prohibited practices.

Mr. T. Merriman said he had noticed that laitance seemed to be absent from specially mixed test specimens but was nearly always present in concrete as it came from a mixer. He had also observed that the quantity of laitance present was proportional to the amount of water used; the more water, the more laitance. This might be due in part to the fact that there was a period during the process when the SO_3 concentration was below that necessary to control the set and that during such period the finer particles of the cement set up as individuals and so lost all of their cementing value and became inert. Another factor that has a bearing is the alkali content of the cement.

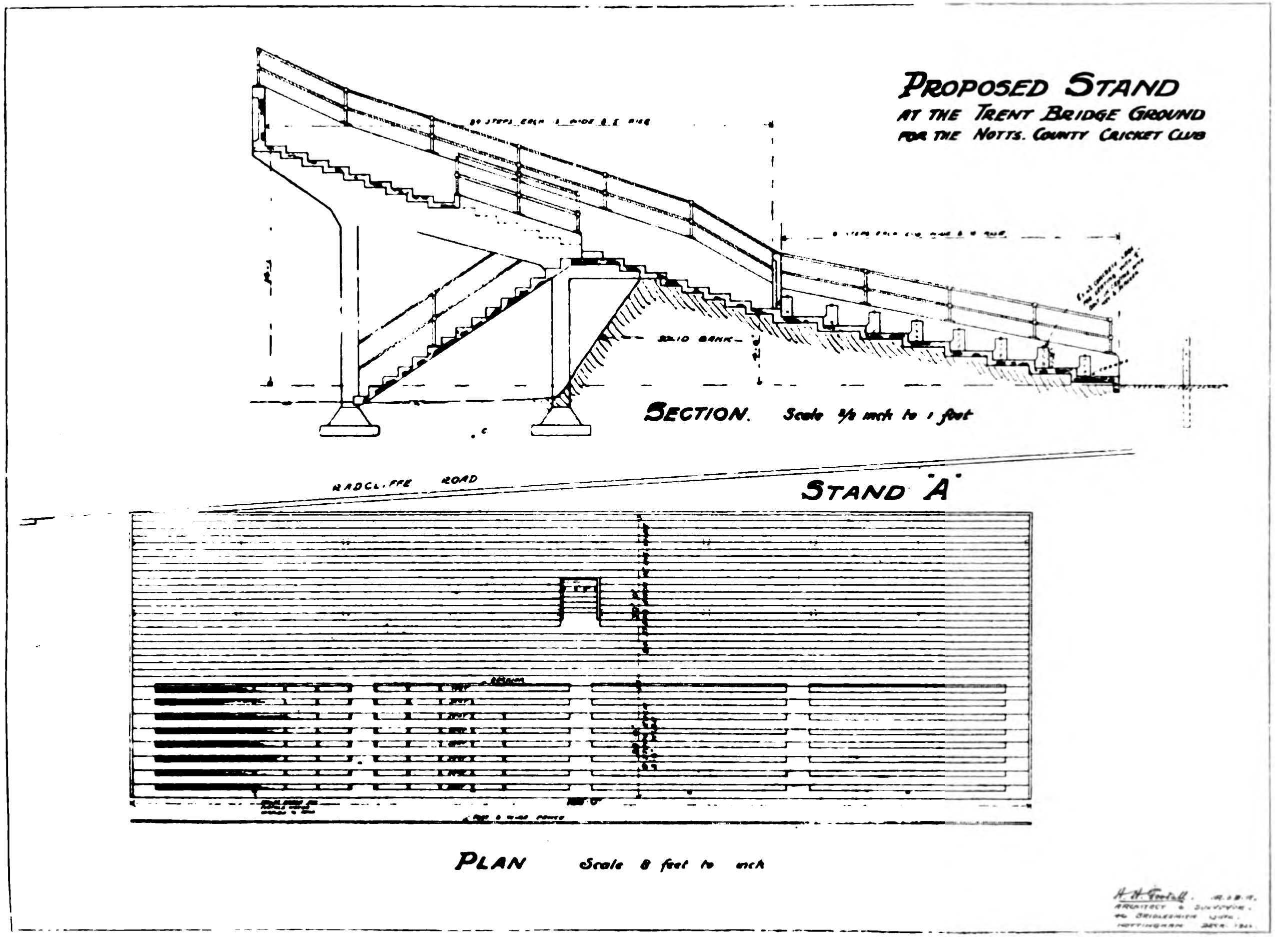
Mr. T. P. Watson said there was no mystery about laitance—its presence was the result of the use of excessive water and it was practically impossible to avoid its forming on concrete placed under water. The excessive water content floated the light impurities in the cement, sand, and coarse aggregate to the surface of the concrete and formed laitance. His experience with "designed" mixtures in the past six months had been that he had not had any laitance form on concrete placed in forms not under water.

Mr. C. A. P. Turner said laitance prevented satisfactory bond between the newer layer and the older concrete. With a decrease in the relative amount of water used the amount of laitance brought to the surface decreased. In bonding the new and the older work it was better to remove the laitance before the older material became hard. It could then be scraped off and the surface roughened with a rake and a good bond for the next layer secured.

Material similar to laitance was developed where the concrete was allowed to flow and separate. Thus, if the workmen filled a beam-box before filling the columns and allowed the material to dribble into the column box, separation occurred and concrete of little strength resulted, which resembled surface laitance. It was about half as heavy as sound concrete and less than a third as strong, and would necessarily have to be dug out and replaced for dependable material in the column core.

In sealing cylinders 40 to 60 ft. under water a foot of top material partly mud and partly laitance was sometimes encountered on the surface and then beneath that the concrete was sound and hard. The layer of inferior material resulted from the fact that the concrete being heavier than the light mud at the bottom of the cylinder, displaced it, forced it to the top along with the laitance and silt which, notwithstanding washing of the bottom with a water jet and taking out everything which the clam would bring to the surface, had been left to be displaced when the seal was made.

Reinforced Concrete Entrance to Underground Station in Paris.


PROPOSED STAND
AT THE TRENT BRIDGE GROUND
FOR THE NOTTS. COUNTY CRICKET CLUB
SOLID BANK
SECTION. Scale ½ inch to 1 foot
RADCLIFFE ROAD
STAND "A"
PLAN Scale 8 feet to inch
ARCHITECT & SURVEYOR
NOTTINGHAM

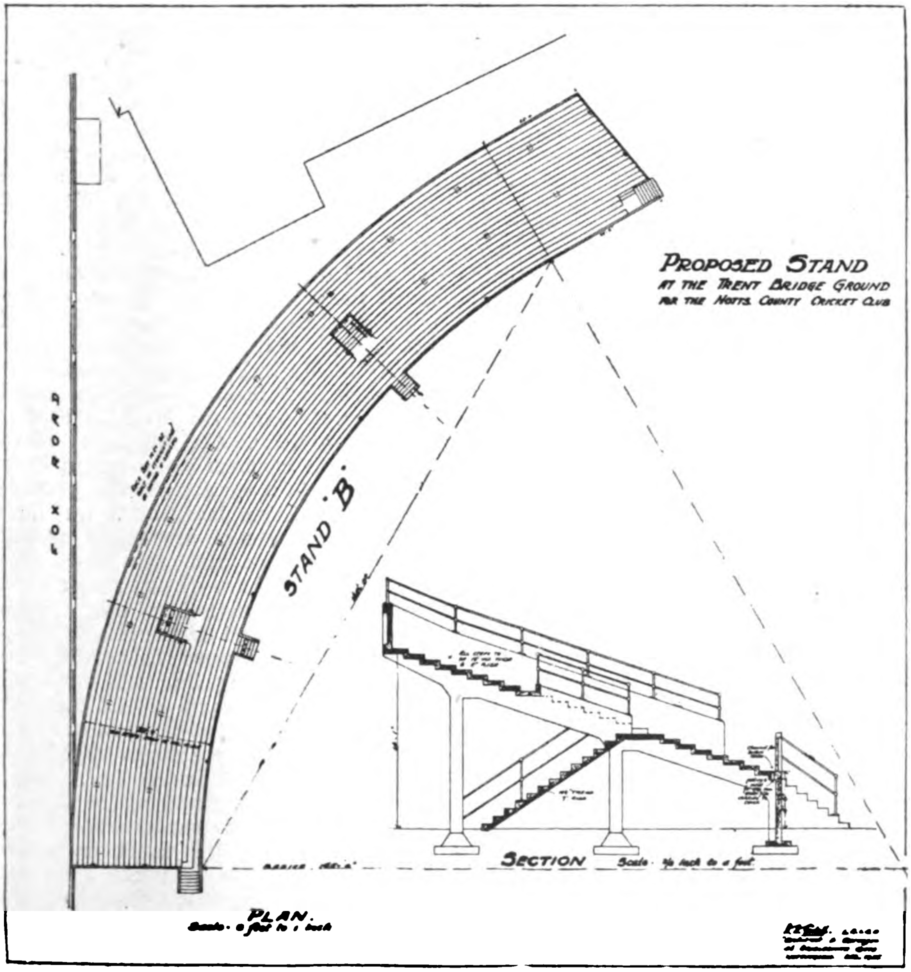
New Grand Stand at Trent Bridge. (*See p.* 387.)

New Stands for the Notts County Cricket Club.

We illustrate plans and sections of the two new stands being built on the Notts County Cricket Club Ground at Trent Bridge in readiness for the first Test Match to be played there on June 12. These stands provide accommodation for 7,000 spectators. In order to have them completed in good time, rapid-hardening Portland cement is being used throughout, with remarkable results. Although not started until February 1, Stand A was completed on April 24, while similar progress is being made with Stand B, which was commenced later. On this work it was found possible to strip the shuttering 48 hours after the concrete was poured.

The stands are in reinforced concrete on the Mouchel-Hennebique system.

In Stand A seating accommodation is provided in front of the barrier by fixing pre-cast blocks on the steps. The usual type of wooden seating is placed on the top of the blocks, and thus seats



New Grand Stand at Trent Bridge.

and footrests are provided on one step only. The upper part of this stand is carried on two rows of reinforced concrete columns, the lower portion being built on the banked earth.

The upper portion of Stand B is supported by three rows of columns. There are several exits at the rear of Stand B, while only one exit is provided at the rear of Stand A. In the case of both stands refreshment rooms and other accommodation is provided beneath the upper portions. The surfaces of all steps, stairs, terraces, etc., are granolithic.

The architect is Mr. H. H. Goodall, L.R.I.B.A., of Nottingham, and the contractors Messrs. F. Evans & Sons, of Bulwell.

Building Trades Exhibition.

THE Building Trades Exhibition held at Olympia last month was undoubtedly one of the finest expositions of modern building materials and plant held in this country. From the point of view of the concrete industry there was little that has not already been described in this journal, and chief interest lay in the stands showing machinery and the pavilion built of "Novocrete," in which the aggregate consists of mineralised wood-fibre in place of sand or gravel. It was seen that this material is admirably suited for the purposes for which it is manufactured, combining lightness with strength and a surface which does not need plastering. It is now being made in blocks and slabs of different shapes and sizes and roofing and flooring tiles of various colours, and its adaptation for other building units is in contemplation.

Surface treatments for concrete were demonstrated on several stands, and the strides made in this direction during the past few years were very evident. The treatments shown included white and coloured cement stuccos, colour washes, and exposed coloured aggregate, in all of which some excellent specimen panels were on view, and no doubt noted by architects who are prejudiced against concrete on account of its appearance, without knowing how it can be improved with but little trouble or expense. The stuccos showing the plasterer's trowel marks were particularly striking and pleasing.

Mixers and block-making machines of the types with which we have become familiar were shown by a number of the leading manufacturers; the types now in use have proved generally efficient, and while minor improvements were to be seen the principles were those already known. On one stand was to be noticed an outfit consisting of a concrete mixer and hoist, both driven by the same engine; the mixer and hoist are so placed that the material is discharged direct from the drum of the mixer into a bucket on the platform of the hoist. A novel feature of this mixer (shown by the Australia Concrete Machinery & Engineering Co., Ltd.) is the shape of the drum; it is called a "cube" mixer, in which the materials are thrown from one square face to another of the drum, which does not contain the usual paddles.

The Concrete Manufacturing Co. (Battersea), Ltd., showed a model of an automatic press for the manufacture of concrete products, in which the whole of the operations from the unmixed materials to the finished product are performed mechanically. Such a machine should have a very large output of high-class concrete articles. On the same stand were shown concrete tiles with a cold-glaze finish in a variety of colours made by Messrs. Superglaze, Ltd., who also exhibited a series of fireplace surrounds cast in one piece but with the surface divided in the form of separate tiles.

Among the firms whose plant is too well known to need description, comprehensive exhibits were shown by the British Steel Piling Co., Ltd., Mr. W. Kennedy, and Stothert & Pitt, Ltd. A new type of steel shuttering in the form of small units was shown by Messrs. Scaffolding (Great Britain), Ltd.

A feature of the stand of the Cement Marketing Co., Ltd., was a section of the new "Vantage" hard court, on which play is possible immediately after the heaviest shower; water poured on the top of the section was seen to percolate through the bottom as soon as applied, a convincing demonstration of the absorptive nature of the material.

The Behaviour of Reinforced Concrete under Tension.

The translation dealing with this subject in the April issue of your valued journal discusses the test results given by M. Greco in "Il Cemento Armato." According to this article, M. Greco found by experiment (centric tension) that the hypothesis put forward by Considère with regard to the ductility of reinforced concrete subjected to tension was again confirmed.

As the question of the admissible tensile stress on concrete in reinforced girders has recently been the subject of much discussion, and various theorists have considered it necessary to recommend a new basis for the calculation of reinforced concrete members, a few remarks on the practical importance of the subject to the structural engineer engaged in static calculations may not be out of place.

It is no doubt generally known that the revised and considerably improved version of Considère's hypothesis published in 1904, with regard to the ductility of concrete in reinforced beams subjected to tension, has in the meantime been cleared up still further by the test results obtained by Kleinogel and Mörsch in the testing station at Stuttgart, and may now be considered to have been thoroughly explored.

From the experiments hitherto conducted by the scientists named, to which must be added the work of von Bach (in Nos. 39 and 45–47 of the "Mitteilungen über Forschungsarbeiten," 1907), of Turneaure (in *Engineering News*, 1904) and of R. Teret ("Etude expérimentale du ciment armé," 1906) we may deduce with a sufficient degree of trustworthiness that:—

(1) The elongation of a beam longitudinally reinforced is greater than that of a pure concrete beam of similar dimensions.

(2) The extent of this additional elongation in concrete (according to a given concrete section, a given external force, and a given ratio of concrete mixture) is dependent on the ratio of reinforcement μ, on the distance of the reinforcement from the edge of the section, on the type of reinforcement (round or section steel), on the method of reinforcement (concentrated or distributed reinforcement, stirrups or "loops"), and on the degree of humidity in storage.

In connection with the various factors under (2), I would remark briefly as follows:—

With regard to the influence of the ratio of reinforcement μ on the ductility of the concrete it may be taken as proved that for rectangular sections with single reinforcement within the limits of $\mu =$ 0·3 to 1·53 per cent. the influence of the ratio of reinforcement is in practice inconsiderable.

With regard to the effect that the position of the reinforcing bar in the concrete has upon ductility, it is proved by test that the greater the distance the bar is from the edge of the concrete the less the ductility.

The choice of the shape of reinforcement has a notable influence on the ductility of concrete under tension. It may be taken as proved by experiment that special shapes, by means of which the bar is prevented from slipping in the concrete, show rather larger figures of ductility in the concrete. The use of Thacher bars resulted in an average increase of 8 per cent. in elongation as compared with round steel bars.

The influence of the method of reinforcement on the elongation of concrete has also been thoroughly explored. It was found that with the distributed arrangement of reinforcement the elongation capacity of the concrete was greater than with concentrated reinforcement, which is explained by the greater area available for taking up the stresses due to slipping.

Moreover it is well known that beams reinforced without stirrups (or loops) have a greater capacity for elongation, as stirrups have a certain influence on the formation of cracks. The first cracks always appear rather earlier in beams with stirrup (or loop) reinforcement.

The degree of humidity in storage has the most decisive influence. It is well known that test beams are always stored in a damp condition, or even under water. As there is no doubt that humidity is extremely favourable to the ductility of concrete, and on the other hand reinforcement causes a decrease in the ductility of concrete with beams stored in *dry* places (contraction), the practical structural engineer will not attach such great importance to the elongation capacity of concrete under tension as certain research workers do. In any case there is no cause to regard this phenomenon as a reason for modifying the basis of static calculations in reinforced concrete construction.

The figures for elongation obtained by M. Greco almost agree with those yielded by previous carefully-conducted tests; but in some cases his values are rather lower than those hitherto published. This is no doubt due to the fact that in order to detect the first fine cracks strong magnifying glasses and probably artificial lighting were used. It may be taken for granted that in cases where the higher ductility figures for the concrete were given the early appearance of the first minute cracks passed unnoticed and the ductility of the concrete was therefore determined with the beam in an overloaded condition. It is possible, too, that the rather lower figures shown by M. Greco's experiments are a result of measuring purely axial tension.

In any case pure bending tests on beams are more reliable than tensile tests, for two reasons. First, because centric tension tests always cause difficulties in practice. Second, as a rule, the length of steel in the headpiece is too short to carry stresses by means of adhesive force, which results in the premature formation of cracks outside the measured length at the point where the shaft of the beam merges into the headpiece.—N.K.

Institution of Structural Engineers.

On April 12 the Piccadilly Hotel was filled to overflowing by members and a large number of guests of the Institution of Structural Engineers on the occasion of the annual dinner of the Institution. A feature of the evening was a cabaret entertainment between the after-dinner speeches.

In proposing " Our Country and Empire," Mr. H. J. Deane emphasised the important part the engineering profession had played in the development of Empire, and in response Sir Alfred Mond referred to the cost of house building, which had, he said, been reduced from £1,000 to £400 per house during his term of office as Minister of Health. On the question of Empire development, he said the combination of chemist and engineer was solving the problems of production and transport in the modern world. The Government could not create; it could only help the engineer and chemist and business man to create. The country could only build up its prosperity on new inventions and new progress. He looked forward to the time when it would be possible to use the vast resources of the Empire as one economical whole, and that was the policy to which he wanted to direct attention. He wanted the British people to turn their eyes from Geneva and concentrate their attention on the development of Empire; the salvation of the British race lay in keeping together and developing the Empire. Our industrial and unemployment problems were inseparable from emigration, and it was in peopling and developing the vast territories overseas that lay the salvation of the country.

" The Learned Professions " was proposed by Mr. J. Mitchell Moncrieff, and in responding Sir William Ellis (President of the Institution of Civil Engineers) said engineers of all kinds owed a great debt to the learned societies for the work they had done in education. The learned societies had raised the educational standard of the profession both as regarded general knowledge and the special requirements in technical subjects. He also dealt with the question of professional registration, which he thought highly desirable in a profession such as engineering which involved the safety of the public.

Mr. Justice Eve and Mr. H. G. Wells also responded.

" The Institution of Structural Engineers and its President " was proposed by Mr. G. Topham Forrest (Architect to the London County Council), and responded to by Sir Charles T. Ruthen, the President, who occupied the chair at the function.

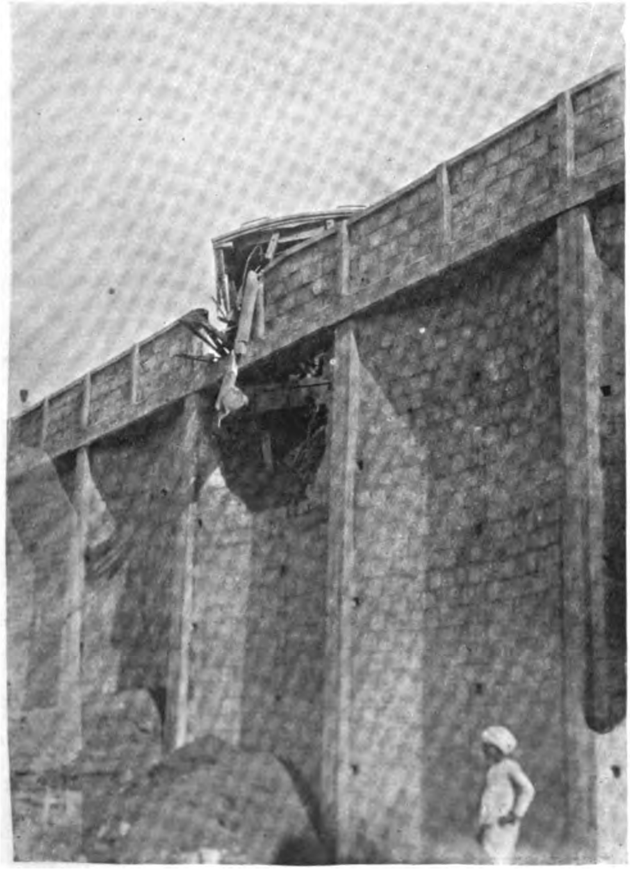
During the evening the President announced that the Institution was purchasing a house in Upper Belgrave Street for the new headquarters of the body, and an appeal was made for funds to carry out the necessary alterations.

Reinforced Concrete Retaining Wall in India.

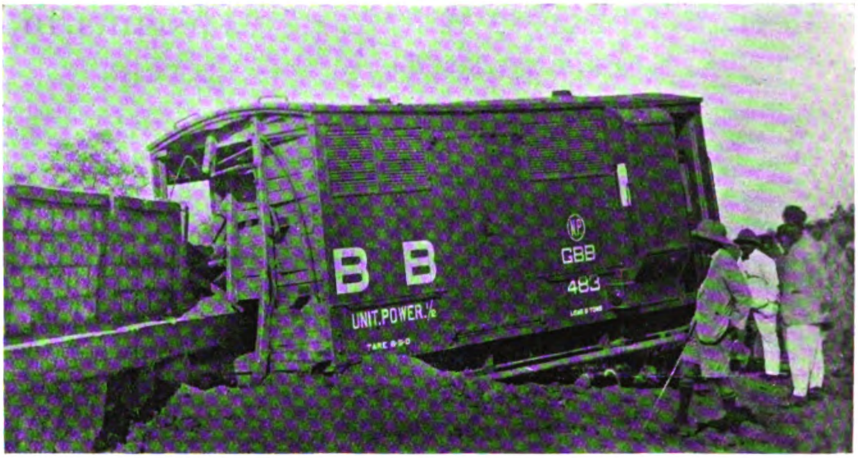
By R. P. MEARS, B.A., M.Inst.C.E.

THE walls illustrated in the April number of *Concrete and Constructional Engineering* were built by the contractors, Messrs. J. C. Gammon, Ltd., of Bombay, and as sections of the work became completed the filling for the approach roads was arranged for by another agency. Distribution of the material and its consolidation was carried out by hand labour, donkeys, and finally by means of broad gauge (5ft. 6in. Indian broad gauge) ballast trains, the locomotives and trucks passing up the grades and over the culverts.

On one side of the railway overbridge there are two approaches at right angles, and the illustrations here reproduced show the result of an accident due to a ballast train being backed up one approach and charging the wall of the approach at right angles to the approach on which the ballast train was moving. As may be seen in the photographs, filling at the point of impact was unfinished and below stringer-beam level, so that the buffer of the brake wagon struck the arched wall panelling below the stringer beam and knocked out a large piece. The framework of the wagon also smashed the



Accident to Retaining Wall.



Accident to Retaining Wall.

parapet, but the stringer-beam held without suffering any injury from the impact. This accident occurred late in the evening. The ballast trucks which were attached to the brake-van lifted the rear wheels of the latter several feet off the ground. The photographs were taken the next day, after the trucks forming the train had been dragged away. The force of impact and the dead weight and thrust on the stringer-beam were therefore much greater than would be apparent from the photographs. Its effect on the brake-van is clearly shown.

The breach in the horizontal arched wall and in the parapet was repaired in a couple of days by the contractors (Messrs. J. C. Gammon, Ltd.) at a cost to the Railway Company of about £2 10s., as it involved nothing more than building in with cement mortar a few superfluous blocks which were on the site.

The steel road overbridge was manufactured in England, and erected at site by Messrs. J. C. Gammon, Ltd. It is of an ordinary plate girder and troughing design, and provides for a roadway of 40 ft. width.

Collapsible Core for Concrete Pipe Construction.

THERE was recently held in Mosman, New South Wales, a public demonstration of a new method of concrete pipe-laying. A trench was prepared in which was placed a long rubber tube, 30 ft. long, connected by pipes with a motor and inflated under pressure until it reached the diameter decided upon—in this instance 14 in. Concrete was then shovelled into the trench and tamped around the rubber core. The core was allowed to remain until the concrete had set, and was then deflated and withdrawn without difficulty, and another 30-ft. section added. The method is a Japanese invention, and is, we understand, being extensively used in the Orient.

Colouring Concrete.

IT is stated that Dr. G. N. White, D.Sc., F.I.C., has discovered a new method of colouring concrete. According to this process the cement is mixed with a solution of dye, which on exposure to the air becomes a permanent and insoluble colouring matter which coats the whole surface of the particles of cement. It is claimed that no more than 0·2 per cent. of colouring matter, or 4½ lbs. per ton of cement, is required, and that experiments so far have been very satisfactory and given excellent results.

Ultimate Strength and Elastic Constants in Compression for Granite Concrete.

W. D. Womersley, M.A., B.Sc., A.M.Inst.C.E.

(*Concluded.*)

Experiments.

THE range of stress obtained on the specimen was from 0 to about 530 lbs. per sq. in. in intervals of about 26 lbs. per sq. in., but no readings could be obtained between 0 and 120 lbs. per sq. in., as the latter figure represents the dead weight of the accumulator tank unloaded ; 530 lbs. per sq. in. was the maximum stress ever applied to a specimen. Water loading and unloading took about three minutes per stress interval, and consequently a complete experiment occupied about 90 minutes. Each specimen was put in the press at an age of from 50 to 60 days, and a number of experiments, varying from four to eight, were made on each. All the experiments for one specimen gave good agreement for the longitudinal strains, but a certain amount of variation was observed in the lateral measurements on one or two occasions. The loading and unloading readings were averaged for each test, and the resulting curve sheared along the strain axis until the no-load average was zero. The whole of the experiments for one series were then averaged ; these figures are given in Table IV, and the curves prepared from them in *Figs.* 6 to 15. The modulii of elasticity and Poisson's ratio are obtained from large-scale diagrams based on these figures (Table III).

TABLE III.—EXPERIMENTAL RESULTS.

Specimen.	Modulus of Elasticity. Lbs. per square inch.	Poisson's Ratio. $= \frac{\text{Lateral Strain.}}{\text{Longitudinal Strain.}}$
A	$4{\cdot}02 \times 10^6$	0·280
B	$3{\cdot}85 \times 10^6$	0·179
C	$4{\cdot}22 \times 10^6$	0·216 to 0·260
D	$4{\cdot}40 \times 10^6$	0·314
E	$5{\cdot}03 \times 10^6$	First Set (*a*) ·338 to ·557 Second Set (*b*) ·125 to ·22 Third Set (*c*) ·305 Average ·291 to ·342

Observations on the Experiments.

During the process of an experiment the temperature of the laboratory was very seldom constant. Small fluctuations of temperature should not affect the great mass of the concrete, but the steel attachments for the extensometers, the extensometers themselves, and the latometer seem to be susceptible to even this small change. Since the coefficient of expansion for steel is about 6×10^{-6} per 1 deg. F., a discrepancy of this order should result per 1 deg. F. change in temperature of the extensometer and attachments. If the temperature is rising this would show itself as "apparent permanent set," but would be an expansion if the temperature change were the other way. This was tested by carrying out an

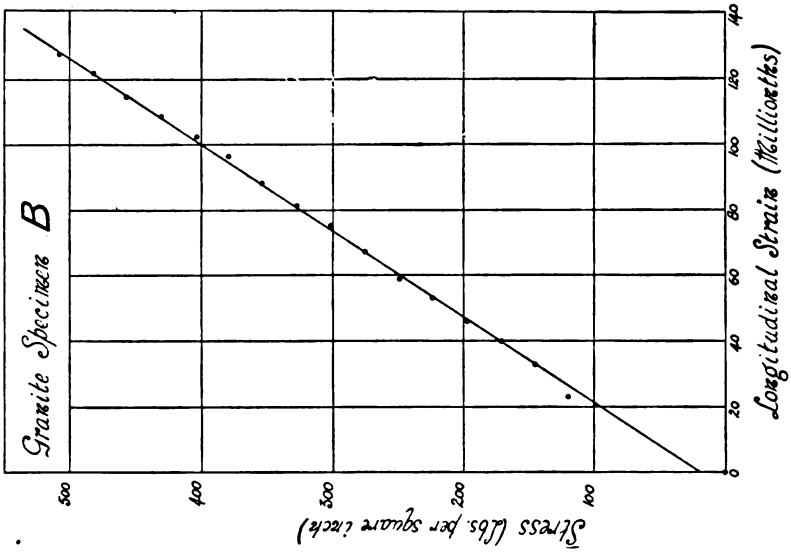

Granite Specimen B
Longitudinal Strain (Millionths)
Stress (lbs. per square inch)
0
20
40
60
80
100
120
140
100
200
300
400
500

Fig. 7.

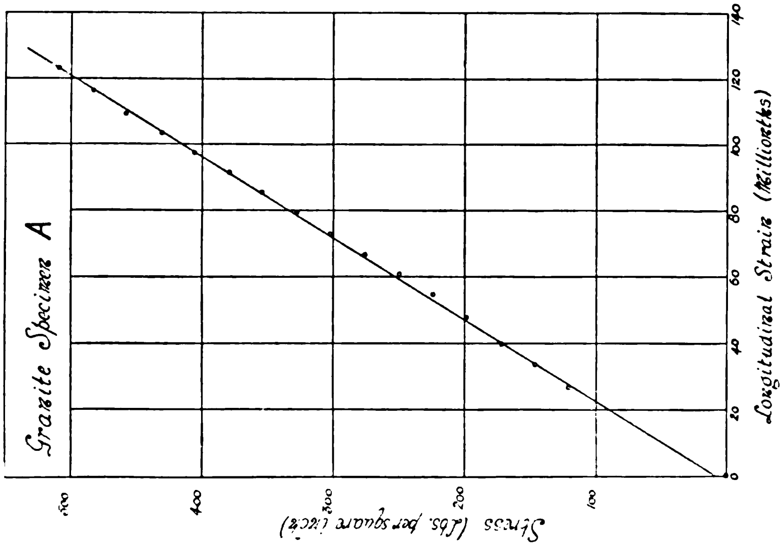

Granite Specimen A
Longitudinal Strain (Millionths)
Stress (lbs. per square inch)
0
20
40
60
80
100
120
140
100
200
300
400
500

Fig. 6.

TABLE IV.—STRESS AND STRAIN FOR THE FIVE SPECIMENS (AVERAGE).

Stress Lbs. per sq. in.	0	120	145	171	197	223	249	275	301	327	353	379	405	430	457	482	508
Longitudinal Strain (millionths).																	
A	0	27	34	40	48	55	61	67	73	80	86	92	98	104	110	117	124
B	0	23	33	40	46	53	59	67	75	81	88	96	102	108	114	121	127
C	0	25	33	40	46	52	58	65	71	77	83	89	95	101	107	113	119
D	0	21	27	34	39	46	51	58	65	71	77	83	88	94	98	104	108
E	0	23	29	35	40	45	50	55	60	66	71	77	81	86	91	96	101
Lateral Strain (millionths).																	
A	0	10·3	12·2	14·3	16·3	18·2	20·0	21·6	23·4	25·1	27·1	28·4	30·6	32·0	33·6	35·5	37·1
B	0	8·0	9·6	11·2	12·6	13·6	14·5	15·6	16·7	17·9	19·1	20·2	21·6	22·6	24·2	25·5	27·0
C	0	6·9	8·5	10·1	11·4	12·6	14·0	15·4	16·9	18·5	20·0	21·4	23·0	24·4	26·1	27·7	29·5
D	0	12·8	14·7	16·9	19·1	21·1	22·8	24·7	26·5	28·5	30·2	32·0	33·8	35·5	37·2	38·9	40·6
E	0	10·1	12·1	14·1	15·8	17·6	19·2	20·8	22·5	24·0	25·7	27·2	28·6	30·0	31·3	32·8	34·2
E (*a*)	0	20·4	24·1	27·4	30·5	33·1	35·4	37·5	39·7	41·6	43·9	45·5	47·2	49·0	50·3	52·0	53·5
E (*b*)	0	2·9	3·5	4·4	4·9	6·2	7·3	8·4	9·5	10·6	11·7	13·0	14·1	15·2	16·2	17·5	18·7
E (*c*)	0	7·1	8·8	10·4	11·9	13·5	15·0	16·6	18·3	19·9	21·4	23·0	24·5	25·9	27·3	28·8	30·4

experiment late at night when the temperature was definitely falling. For the specimen " D " six experiments were made at about the same time on consecutive days, commencing about 3 p.m. For about six hours previous to this the extension meter and latometer were observed at regular intervals with the specimen unloaded and also a delicate thermometer placed touching the concrete with its bulb on the air side covered with a layer of about ½-in. of plasticene. These readings are given in Table V, and shown graphically in *Fig.* 16. The first set was taken previous to the first loading of the specimen. For the first and second sets, before and after the first experiment respectively, it will be noticed that for a given temperature there has been an apparent contraction of the concrete as a result of the first experiment, but that nearly all the remainder show expansion. On this account permanent set, if any, is completely clouded by the temperature effect. It is considered that the difference in the readings corresponding to a given temperature is due to the different relative temperatures of the concrete and steel. Thus, if the steel temperature during an experiment is increasing uniformly the loading slope of the stress-strain curve will be too low and the unloading slope too high by an equal amount. Hence the average of the loading and unloading should give the true slope, and also the true zero will be the average one. This is the reason for taking the mean readings and shifting the zero for all the experiments.

Poisson's Ratio for specimen " E " as obtained in the first set of readings (*a*) is quite impossible, and consequently when all the other specimens had been tested (" E " was the second) " E " was put in the press again and a further set of five experiments made (*b*). It is not known how these two sets are related in azimuth, as the specimen was put in the press haphazard each time. The difference between the two was, however, so astonishing that after the second set was complete the specimen was rotated through 90 deg. about a vertical axis with respect to the instruments and the press and a further two experiments made (*c*). It will be noticed that (*c*) lies roughly midway between (*a*) and (*b*) and very close to the average of the three sets. These variations cast doubt on all the experiments on the lateral strain, and consequently when the next specimen was ready for test it was decided thoroughly to investigate the point. Five series of experiments were made with three experiments in each series, and the specimen was rotated

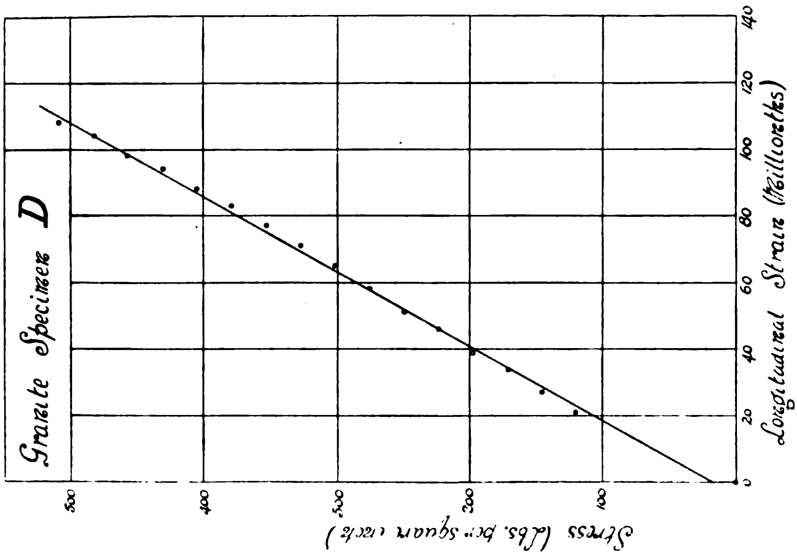

Granite Specimen D
0
20
40
60
80
100
120
140
Longitudinal Strain (Millionths)
100
200
300
400
500
Stress (lbs. per square inch)

Fig. 9.

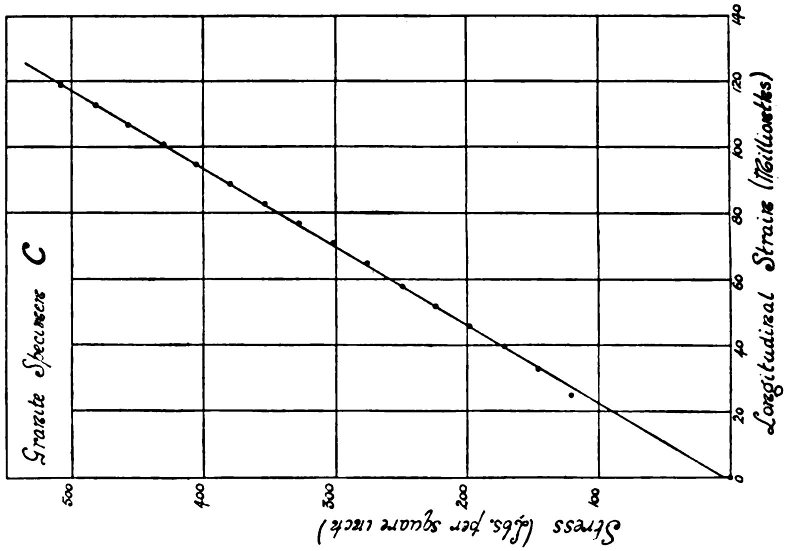

Granite Specimen C
0
20
40
60
80
100
120
140
Longitudinal Strain (Millionths)
100
200
300
400
500
Stress (lbs. per square inch)

Fig. 8.

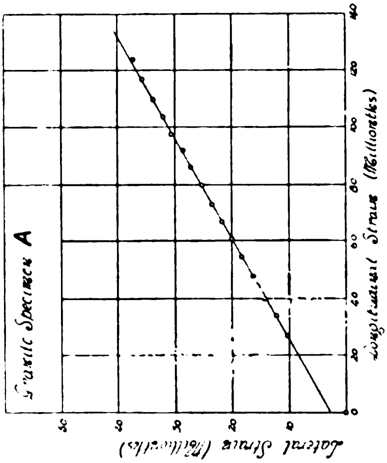
TABLE V.—TEMPERATURE STRAINS.

No.	Temp. ° F.	Mean Extensometer Readings, 50,oooths.	Latometer Reading converted to Lateral Strain.
1	47·20	265	89·3 × 10⁻⁶
	48·50	248·5	71·5
	50·30	239	66·0
2	45·75	264	82·0
	46·40	256	75·0
	47·80	243	61·6
	48·30	236	57·6
	49·50	228·5	48·2
	50·00	225·5	—
3	51·20	240	62·5
	53·00	224·5	47·5
	53·90	221	43·5
4	53·95	230	44·1
	54·50	224	41·0
	55·00	219	38·9
	55·30	217	38·3
5	53·50	245·5	62·2
	54·00	240·5	55·2
	54·60	234	49·1
	55·00	288	46·4
	55·35	227·5	43·5
6	52·20	244	60·4
	52·60	240·5	49·6
	54·10	234	44·1
	54·30	231·5	42·3
	54·30	234·5	43·9

through 30 deg. between each series. As only a small difference was obtained in this case between the various positions, it seems evident that specimen "E" is not at all homogeneous, and this is probably due to the fact that one of the rammers was not doing quite as much work as the others.

The thermometer on the concrete has been observed to rise comparatively rapidly after the application of the first load and to go on rising steadily but more slowly during the remainder of the loading. During unloading the thermometer continued to rise, but still more slowly, remained constant or fell slightly until the bottom load was reached. In several cases when the bottom load was taken off a rapid fall in temperature was noted. The sudden rise and fall at the beginning and end of an experiment was of the order of 0·05 deg. F. to 0·10 deg. F., and the total rise about 0·20 to 0·25 deg. F. In order to examine this temperature change more definitely a specimen was cast in which thermo-couples were embodied within the concrete capable of detecting temperature changes of the order of 0·02 deg. F. and arranged in the mid-cross section, as shown in *Fig.* 17. Although the whole stress change of 530 lbs. per sq. in. has been applied suddenly it cannot be said that the temperature change has been observed definitely in the thermo-couples. The diurnal change of temperature of the concrete is so very much greater that the small quantities it is desired to find are hidden. The change

Fig. 11.



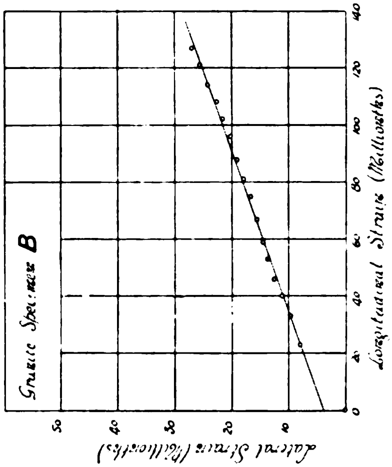


Fig. 12.

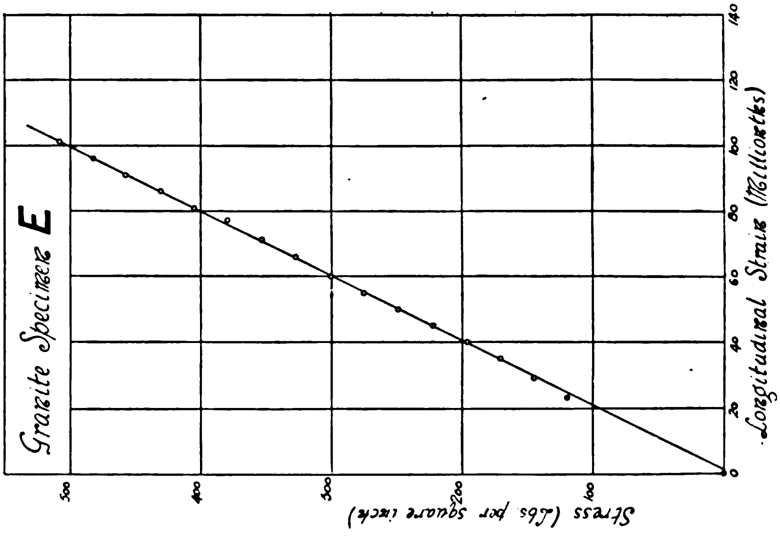


Fig. 10.

Fig. 13.

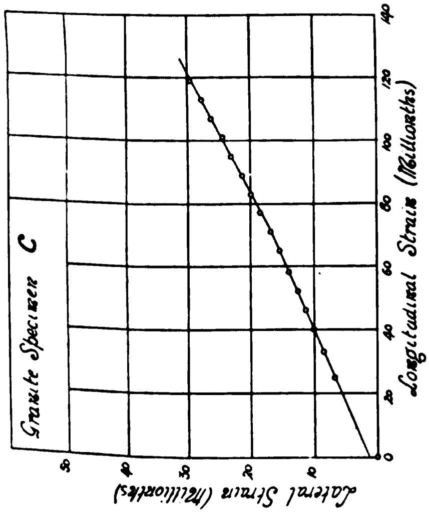


Fig. 14.

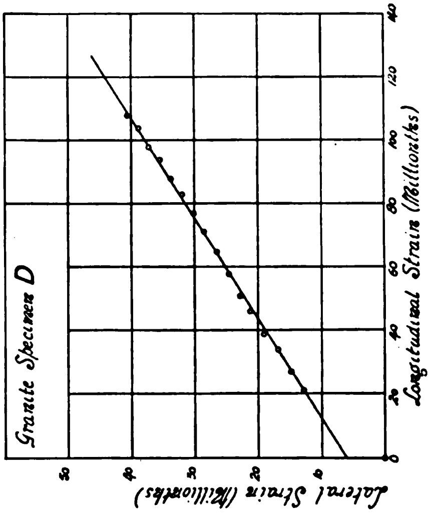


Fig. 15.

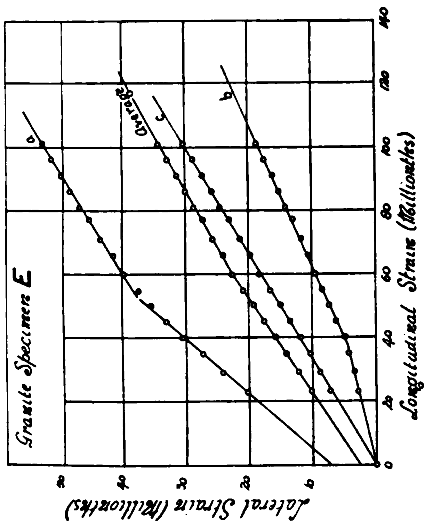
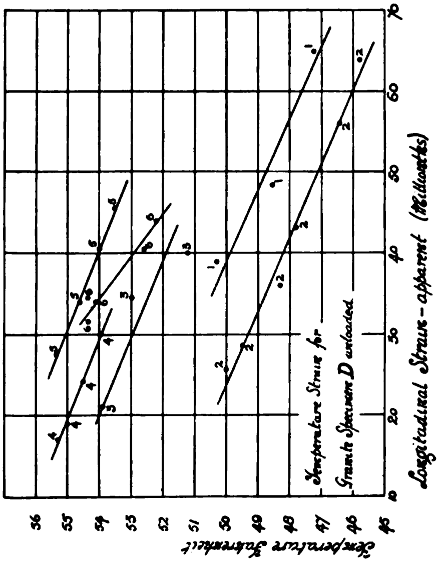


Fig. 16.



of temperature being sought was that due to the adiabatic change of stress and calculated from the following thermodynamic relation :

$$\delta T = \frac{T.v.a.\delta p}{K_\varrho}$$

where T is the absolute temperature, about 290 deg. C. in given case.

δT is the change of temperature to be found.

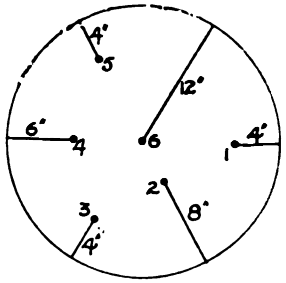
v is the volume per unit mass, $\frac{1}{140}$ cu. ft. per lb.

a is the coefficient of linear expansion, 10×10^{-6} per 1 deg. C.

δp is the change of pressure in lbs. per sq. ft.

K_ϱ is the specific heat of the concrete—no value has been found, but it has been assumed to be about 0·02 C.Th.U. per 1 deg. C.

When these figures are introduced into the equation the rise of temperature for the whole range of stress up to 530 lbs. per sq. in. should be about 0·10 deg. F. From the thermo-couple experiments it would appear that the figure is an over-estimation, and it is therefore thought that the effect may safely be neglected.



Position of Thermocouples in Specimen G

Fig. 17.

In the preliminary elasticity tests, previously mentioned, the readings of the two extensometers were on some occasions widely different ; as much as 30 per cent. was not uncommon. This was remedied by paper packing above the top oak board. The mean of the two extensometers was, however, always the same whether packed or unpacked. On one occasion one side was packed until the other side actually showed tension due to the non-axial effect of the load, but the average was still the same. The arrangement of the extensometer is thus considered to be eminently satisfactory.

The very regular high values obtained for the modulus of elasticity suggested that there must be something different in the method of manufacture from that generally employed. As a number of reinforced concrete bridges were being built near the laboratories the opportunity was taken to get a big specimen and a number of cubes made by the engineer in charge of this work.

Specimen " F " (Actual Bridge Material).—The aggregate was the same as that used by the author, but the sand was from Leighton Buzzard. The cement was the ordinary Portland cement of the same firm supplying the author's quick-hardening variety. The concrete was 1 : 2 : 4 by volume and hand-mixed to the usual consistency. The quantity of water was not known, but the mix appeared wetter than " A." There is one definite difference, however, in the manufacture. The lorry carrying the mould was wheeled some 200 yards from the job into the laboratory as soon as the mould had been filled. The specimen was tested at about six weeks old in five different positions varying by 30 deg. in azimuth. The results of these tests are as follows :

TABLE VI.—SPECIMEN F.

Position.	1	2	3	4	5
Modulus of Elasticity, Lbs. per square inch	$4·95 \times 10^6$	5·20	4·60	4·87	4·87
Poisson's Ratio	0·229	0·264	0·269	0·206	0·226

It will be seen that there is a 1·2 per cent. variation in the modulus of elasticity and a 14 per cent. variation in Poisson's Ratio above and below the mean. The modulus of elasticity figures show about the general accuracy attempted, but the Poisson Ratio figures indicate that complete homogeneity cannot be obtained by hand manipulation. The tensile tests on the cement in this specimen were as follows :

Neat Cement.		3 to 1 Sand.	
7 days.	28 days.	7 days.	28 days.
780 lbs. per sq. in.	909	513	610

The crushing tests on the cubes are as under:

	Lbs. per square inch.		
30 days	3,500	3,730.	Average 3,615
60 ,,	3,390	3,010	,, 3,200
90 ,,	4,330	3,680	,, 4,005

The cubes from which these tests are obtained were made whilst the large specimen was being cast and from the same mix. Two other samples of the same type of concrete made into blocks 12 in. by 12 in. by 6 in. had previously been tested and gave the following results : " A " clean water, 1,780 lbs. per sq. in. ; " B," soft soapy water, 1,490 lbs. per sq. in. These specimens were made up by the engineer to test the effect of the soft soap used in the forms.

The author was still dissatisfied with the high value of the modulus of elasticity and the crushing strengths, and consequently another big specimen was made in which the thermo-couples were embodied.

Specimen " G " Thermo-Couples.—The same solid ingredients as " A," " B," " C," etc., were used with the exception of the cement, which was of the ordinary Portland variety and the same as in " F." The water was increased to 210 lbs. and the mixing done on a flat concrete floor. The mix was so wet that ramming did not appear to be of much value. A certain amount of ramming was done, but not so much as in the earlier specimens. Ten 4 in. cubes were made from the mix and twelve 4·375 in. diameter by 6 in. long cylinders. The cylinders received a considerable amount of ramming. The cubes only received a little ramming. The crushing test specimens were taken out of the moulds after 48 hours and placed on a shelf in the laboratory and after two or three days appeared perfectly dry and remained so. The tests are as follows :

Tensile Tests of Cement. lbs. per sq. in.

Neat Cement.		3 to 1 Sand.	
7 days.	28 days.	7 days.	28 days.
776	785	(*a*) 356	491
		(*b*) 439	565

(*a*) and (*b*) are both made from standard Leighton Buzzard sand purchased from different vendors ; (*b*) was quite a uniform white sand ; (*a*) was of a reddish brown colour. The price of (*b*) was about three times that of (*a*).

Crushing Tests.

30 days.			Lbs. per square inch.		
4 in. cubes	672	786	815	Average	758
4·375 in. cylinders	1,193	1,284	1,312	,,	1,263
90 days.					
4 in. cubes	974	1,125	1,256	,,	1,116
4·375 in. cylinders	912	998	1,043	,,	985
6 months.					
4 in. cubes	956	1,006	—	,,	980
4·375 in. cylinders	789	990	1,023	,,	935

The large specimen was tested at 25 to 29 days, and the relationship of stress was perfectly linear. The modulus of elasticity as the average of five tests was found to be $2{\cdot}73 \times 10^6$ lbs. per sq. in., and Poisson's Ratio 0·199. The rise in temperature during setting was taken for this specimen by means of the thermo-couples, and is shown graphically in *Fig.* 18.

General Conclusions.

With the exception of the specimen " G " the modulus of elasticity in all the specimens tested has been very high in comparison with the usually accepted value, ranging from 4 to $5{\cdot}5 \times 10^6$ lbs. per sq. in. The modulus does not seem to depend particularly on the kind of material used. The quantity of water has a small effect, an increase in the quantity in general reducing the modulus. The amount of ramming and vibration seems to be the determining factor, and variation in the treatment of the mould when full of wet concrete can apparently produce almost any result desired within the possible range. At a later date a specimen will be made without any ramming, but with the mould kept in a state of violent vibration.

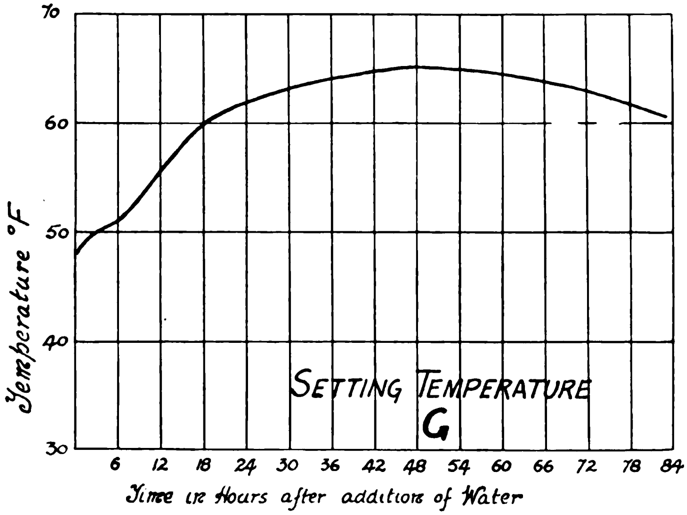


Fig. 18.

With respect to the crushing tests, the opinion is held that they are not at all representative of their allied large specimens on account of the difference in method of manufacture, and that the only possible way of determining the ultimate strength of a large specimen is to cut specimens directly from it. Perhaps the pneumatic vibration method may produce similar material so long as there is no personal element in the method of manufacture.

In general, the author believes that laborious grading of sand and aggregate is a waste of time, as with the usual methods of casting concrete in practice ramming and vibration of the moulds is almost non-existent so that the material never has a chance to arrange itself in the position of maximum density.

The very low values for the crushing strength of the initially very wet, partially rammed, air dried specimen, is alarming and indicates very definitely the deleterious effects of excess of water and insufficiency of consolidation.

Effect of Road Surfaces on Traffic.

FORD MOTOR COMPANY ADVOCATES CONCRETE.

A recent issue of the "Ford Times" says: " One important factor which must play a considerable part in reducing the cost of motoring is undoubtedly the introduction of concrete roads. Such a system of construction has already passed its experimental stage—with honours—and statistics are available which prove that it entails both a lower consumption of petrol and a longer life to the car. For example, careful tests made with a number of lorries showed that these did 11·78 miles to the gallon on a concrete surface, and only 9·48 miles on bituminous macadam. On an earth road in average condition the figure fell to 5·78 miles.

" It is obvious that the principal cause of deterioration lies in the uneven character of the road over which a car has to travel. The durability of concrete largely eliminates this source of trouble, and channelling and potholes do not occur. This fact, while saving the pocket of a motorist by reducing depreciation of his car, represents an important economy for the authority responsible for the maintenance of the road. Records compiled in America in connection with roads carrying over 2,000 vehicles daily show that the maintenance costs of concrete roads were only 27·4 per cent. of the costs of those constructed of macadam.

" Another fact which calls for the introduction of concrete in our highways is the increased element of safety afforded by such a surface. The risk of skid becomes practically nil—indeed, on concrete such a feat is difficult to accomplish even when seriously attempted.

" At the bends of the roads also banking can be readily and satisfactorily made with this material, which does not ' channel.' At such a spot the car can travel round the curve on its correct side instead of taking the middle of the road, or even the wrong side, at the risk of collision with an approaching vehicle.

" In the States to-day, when every second man you meet owns his car, there are 44,000 miles of concrete road. That fact speaks for itself. There are to-day only about 300 miles of such roads in Great Britain, but every motorist who has ever driven on them knows that there is nothing to equal concrete for road surface."

Back Number Wanted.—A subscriber desires to purchase a copy of " Concrete and Constructional Engineering " for January 1925. Replies should be addressed to Box No. 1297, " Concrete and Constructional Engineering," 20, Dartmouth Street, Westminster, S.W.1.

Questions and Answers relating to Reinforced Concrete.

Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

Water for Mixing Concrete.

QUESTION.—When is the correct time to add the water in machine mixing? I have seen it added (*a*) wholly before the dry cement, sand, and ballast are shot in from the hopper; (*b*) all together after the dry materials have been given a turn or two; and (*c*) about three-quarters with the dry material and the remaining quarter to wash out the last of the mix from the mixer after as much mixed concrete has poured into the skips as will come out without the addition of the last fourth part of water. The idea in methods (*a*) and (*c*) appears to be to keep the mixer clean, as if the minimum quantity of water is used the mixed concrete will not flow properly from the machine.—D. J. M.

ANSWER.—The right time to add water in machine mixing is after the other materials have been introduced and mixed dry. It should be introduced fairly gradually, but the mixer should be given ten to twenty turns after the last water has been added, and on no account should one-quarter of the water be left till the last to wash out the last of the mix from the mixer. The mixer should be cleaned after the day's work is done by washing out thoroughly with clean water. If the mixed concrete with the proper quantity of water will not discharge properly from the machine it is a criticism of the machine.

Silica Sand.

QUESTION.—I understand that sand for concrete should preferably consist of grains of silica. What is the particular advantage of this material? Does a fine sand increase contraction in setting, and so tend to cause cracks?—D. K.

ANSWER.—The advantage of sand consisting of grains of silica is that it is an impervious material, and the mortar is therefore less liable to contraction on setting and is a better protection to the steel against corrosion. A fine sand requires more cement to cover the increased surface of its particles, and therefore greater contraction is produced. If a fine sand is used with the same percentage of cement as a coarse sand, increased contraction will be avoided, but the mortar will not then be so strong or so dense, and corrosion of the reinforcement may result.

Centering for Spiral Staircase.

QUESTION.—In the case of a reinforced spiral staircase, 15 ft. between landings, 8 ft. outer and 4 ft. inner diameter of well, please advise how to develop the exact areas of shuttering for the (under) slab of the stair, and the (vertical) inner face of the cylindrical wall. What are the best scantlings of timber (redwood, say, or perhaps 3-ply timber) for these areas? If 3-ply timber is not used, it is proposed to place the boards vertically for the vertical cylinder wall and to concrete this 15-ft. height in three shutter lifts. The outer face of the cylinder is proposed to be shuttered on the same principle.—H. A. M.

ANSWER.—A common method of centering such a staircase is to construct the inner cylinder with framing and nailing on to it 3-ply for the widths where the staircase actually comes. From this inner cylinder horizontals are taken to the outer wall at frequent intervals (say, one per step), and 3-ply timber is bent to these and nailed at intervals. The inner centering to the cylinder may consist of vertical tongued-and-grooved boards, nailed to timber centres about 3 ft. apart and taken up the full height, cutting gaps in it where necessary to accommodate the staircase. The centering to the outside is preferably made in the form of vertical tongued-and-grooved boards nailed to timber centres, making a shutter about 3 ft. high in four lengths with connecting screws to tighten them up. These shutters are raised after each day's concreting to prepare for the next, and so give ample access to the reinforcement in the cylindrical wall and enable the concrete to be put in under adequate inspection.

Design of Silos.

QUESTION.—(1) In the design of a reinforced concrete silo, 12 ft. in diameter, I find that the footings will require to be 24 in. wide. The wall supported is 6 in. thick, and carries a load of 8,500 lbs. per linear ft. Calculation for bending and shear gives an effective depth of 7 in. with $\frac{1}{2}$-in. rods at 12 in. centres. Bond stress, however, gives a "bond area" of about 7 sq. in. (safe stress 100 lbs. per sq. in.). Is the result reasonable, and if so, how is this stress to be met?

(2) Is it the usual practice to design for combined bending and direct stresses due to wind and dead loads in reinforced concrete columns carrying the ends of a steel roof truss? The columns are unsupported in the direction of bending, and carry no load apart from the roof.—A. W. C. S.

ANSWER.—(1) The difficulty is a real one and must be met by the use of smaller bars at closer centres, by increasing the depth of the footing, or by reducing the stress in the rods, or a combination of these methods, until a satisfactory bond stress is obtained.

(2) If concrete columns are subject to wind and dead load it is usual to design them for combined bending and direct stresses accordingly.

Removing Cement Stains.

QUESTION.—I am employed on the construction of a very large building which is faced with a close-grained pink-coloured sandstone. During construction this stone has become considerably stained with cement. I should be very glad of hints as to how these cement stains can be removed.—F. C. B.

ANSWER.—Stone which has been stained with cement can have the stain removed by the application of dilute hydrochloric or acetic acid and then washing down with plenty of water. Inasmuch as the salts will continue to come through the stone for some months, this process may have to be repeated several times.

Key for Plaster.

QUESTION.—A specification states that all reinforced concrete work is "to be left rough to receive plaster"; how is this to be done, short of hacking the surface after casting?—F. C. B.

ANSWER.—To leave reinforced concrete work rough to receive plaster it is possible to use a mould with ridges left on it so that the necessary roughnesses will be cast on the concrete. It is, however, more usual in practice to hack the surface, though the first method gives the better key for the plaster.

Book Reviews.

Practical Road Engineering. By H. E. Goldsmith.

(London: Crosby Lockwood & Son. Price, 25s. net.)

THIS is a comprehensive volume of over 200 pages covering the whole field of road construction. Concrete roads are dealt with in a separate chapter, which could, we think, have been extended with advantage. We find, for instance, the question of water dismissed in three lines, while the vitally important question of water content does not appear to be dealt with at all. Neither can we find any reference to rapid hardening Portland cement, although it has been in use for all-concrete roads and foundations for other types of roads for two years or so and is revolutionising ideas on road construction. The chapters dealing with the types of road which find more favour with the author, however, are more authoritative, while the notes on setting-out are of use to those concerned with any type of road construction.

"Laboratoriumsbuch für die Portland-zementfabrik." By Franz Killig.

Second Edition, 144 pp. (Charlottenburg; Zementverlag G.m.b.H.)

THIS is a useful handbook for chemists on cement factories and for those whose occupation calls for the analysis and testing of cements. The methods of chemical analysis are described for cement and its raw materials, coal, and flue gases. The routine to be observed by chemists for the control of quality on cement works is outlined, and there are useful chapters on the investigation of faulty concrete, effloresence on concrete, the presence of anhydrite in gypsum, detection of slag in cement, etc. The second half of the book deals with the physical testing of cement and pays particular attention to tests for soundness. A summary is given of the standard cement specifications of the principal nations of the world. We regret that the book is written in a language that makes it unavailable for many who would otherwise find it valuable.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	6
Thames ballast	„	10	6
Broken brick (¾ in.)	„	11	6
Best British Portland Cement	per ton 58*s.* to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10*s.* per ton extra		
"Super-Cement"	per ton 88*s.* to	93	0
"Lightning" Brand Aluminous Cement	„ 100*s.* to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	*Sawn.* d.	*Wrot.* s.	*Wrot.* d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £20 „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
5/16 in. to ½ in. Rounds	„	10	9
⅜ in. Rounds	„	11	0
¼ in. Rounds	„	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per foot cube	1	11
Do.	do.	in columns	„ „	2	1
Do.	do.	in beams	„ „	2	3
Do.	do.	in floor slabs 4 in. thick	per yard super	6	0
Do.	do.	in floor slabs 5 in. thick	„ „	7	6
Do.	do.	in floor slabs 6 in. thick	„ „	9	0
Do.	do.	in floor slabs 7 in. thick	„ „	10	6
Do.	do.	in walls 6 in. thick	„ „	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
„ 5/16 in. to ½ in.	„	21	6
„ ⅝ in. to 2⅞ in.	„	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	„ „	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	„ „	1	1½
Do. do. as last, in narrow widths	„ „	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	„ „	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

ADWICK-LE-STREET. — *Houses.* — The U.D.C. proposes to erect 120 houses.

ARMAGH.—*Houses.*—The R.D.C. has prepared a scheme for the erection of 105 houses at a cost of £37,290.

BALLYCASTLE.—*Houses.*—The R.D.C. proposes to erect 60 cottages.

BARNET. — *Concrete Houses.* — The R.D.C. is considering the question of erecting concrete houses.

BATH.—*Houses.*—The City Engineer has prepared plans for a housing scheme, estimated to cost £200,000.

BATH.—*Bridge.*—The Corporation proposes to spend £50,000 in replacing the Old Bridge.

BEVERLEY.—*Houses.*—The T.C. has purchased a site of 40 acres for housing purposes.

BLACKPOOL. — *Houses.* — The Estates Committee of the Corporation has prepared a scheme for the erection of 500 houses.

BLAYDON.—*Houses.*—The U.D.C. has applied for permission to build 180 houses.

BOGNOR.—*Road.*—The U.D.C. proposes to reconstruct Upper Bognor Road with reinforced concrete.

BOURNEMOUTH.—*Concrete Sea Wall.*—A concrete sea wall is to be built at the eastern end of Boscombe Promenade.

BOWNESS.—*Promenade.*—A scheme is being considered to extend the promenade on the shore of Lake Windermere. The cost is estimated at £13,000.

BRISTOL.—*Bridge.*—A suggestion for the construction of a bridge over the River Avon is being considered by the Corporation.

BUCKHAVEN.—*Houses.*—The T.C. has applied for sanction to a loan of £120,000 for the erection of 300 houses.

CHESTER. — *Concrete Road.* — The Cheshire C.C. proposes to lay an experimental stretch of concrete road.

COATBRIDGE.—*Houses.*—The T.C. proposes to purchase a site on which to erect 500 houses.

COLCHESTER. — *Houses.* — Application has been made for sanction to a loan of £25,170 for the erection of 51 houses at Lexden.

CONGRESBURY. — *Road.* — A sum of £8,500 is to be spent on the construction of a by-pass road.

DEWSBURY.—*Houses.*—The Housing Committee recommends the Corporation to build 179 houses at Ravens Lodge.

DUNDEE.—*Road.*—A road is to be constructed from Ancrum Road to Dullideph Road.

FEATHERSTONE.—*Houses.*—The U.D.C. has applied for a loan of £21,940 for the construction of 50 houses at Streethouse.

GARSTANG.—*Bridge.*—The R.D.C. proposes to erect a bridge across the River Wyre.

GLASGOW.—*Bridge.*—The Corporation and the Clyde Navigation Trust are discussing the question of erecting a bridge over the Clyde at Finnieston.

GLENCONRIE.—*Bridge.*—A sum of £975 is to be spent on the construction of a bridge over the Don at Glenconrie.

GREAT YARMOUTH.—*Bridge.*—A bridge is to be constructed to replace the old Haven Bridge.

GRIMSBY.—*Bridges.*—The T.C. has decided to spend £55,000 on reconstructing road bridges.

HAZEL GROVE.—*Houses.*—The U.D.C. proposes to erect 48 houses on the Bosden Fold estate.

HIGHAM FERRERS.—*Houses.*—The T.C. has applied for sanction to erect 20 houses.

HULL.—*Houses.*—The Corporation has purchased a site of 30 acres for a housing scheme.

HULL.—*Road.*—The Corporation proposes to construct a road through Inglemire Lane on the Beverley Road. The cost is estimated at £80,000.

HULL.—*Warehouse.*—The Corporation is to spend £425 on concrete work at the Wilberforce warehouse.

LEICESTER.—*Cooling Towers.* — The City Council proposes to erect two concrete cooling towers at the central generating station. The cost is estimated at £23,236.

LINCOLN.—*Houses.*—A plot of 17 acres has been bought by the local Co-operative Society for the erection of 200 houses.

LYTHAM ST. ANNES.—*Concrete Roads.*—The Corporation proposes to lay two all-concrete roads.

NELSON.—*Houses.*—The T.C. proposes to erect 100 houses on the Hodge House estate.

Newcastle (Ireland).—*Bridge.*—The U.D.C. has prepared a scheme for the construction of a bridge over the Tullybrannigan Road.

Newton Abbot.—*Houses.*—A scheme is being prepared for the erection of 100 houses at Broadlands.

Oldham.—*Piling and Foundations.*—The proposed new generating station to be built at Oldham will include the construction of reinforced concrete piles and foundations.

Ossett.—*Roads.*—The Borough Surveyor has been instructed to prepare plans for the construction of two streets leading off Queen's Drive.

Oswestry.—*Houses.*—The R.D.C. proposes to erect 50 houses at St. Martin's.

Otley.—*Houses.*—The U.D.C. proposes to built 134 houses.

Penmaenmawr. — *Reservoir.* — The U.D.C. has applied for permission to construct a reservoir.

Peterborough.—*Houses.*—The City Council is considering a scheme for the erection of 100 houses.

Plymouth.—*Culvert.*—The T.C. proposes to spend £5,000 on the construction of a culvert at Pennycomequick.

Poole.—*Houses.*—The T.C. has applied for sanction to a loan of £80,000 for housing purposes.

Portsmouth.—*Bridge.*—A bridge is to be constructed across Chandos Street, at Landport.

Rhyl.—*Pier.*—The U.D.C. has applied for a grant of £15,000 for the reconstruction of the pier.

Ripon.—*Houses.*—The Corporation is considering a scheme for the erection of 130 houses at Aismunderby.

Rochdale.—*Houses.*—The Corporation proposes to build 360 houses each year for the next three years.

Rotherham.—*Houses.*—The T.C. has applied for a loan of £30,420 for the erection of 72 houses on the Eastdene site.

St. Thomas (Devon).—*Houses.*—The R.D.C. proposes to build 96 houses.

Sedgefield. — *Houses.* — The R.D.C. proposes to build 100 houses.

Seghill.—*Houses.*—The U.D.C. proposes to build 70 houses.

Senghenydd.—*Bungalows.*—The Caerphilly U.D.C. proposes to erect 60 bungalows at Senghenydd.

Shoreham.—*Pier.*—The Shoreham Harbour Trustees have agreed to reconstruct a further 250 ft. of the pier. The work will be carried out mainly in mass concrete.

Shrewsbury.—*Houses.*—The Corporation proposes to build 50 houses on the Racecourse estate. The cost is estimated at £21,450.

Southport.—*Houses.*—The Corporation Housing Committee recommends the erection of 100 houses at Shaftesbury Road.

Southwick-on-Wear.—*Houses.*— The U.D.C. has applied for permission to erect 100 houses on the Marley Pots estate.

Sowerby. — *Bridge.* — The Thirsk R.D.C. has instructed the Surveyor to prepare plans for the construction of a bridge over the Ford at World's End, Sowerby. The cost is estimated at £1,000.

Streethouse.—*Houses.*—The Featherstone R.D.C. has applied for sanction to a loan of £21,940 for the erection of 50 houses.

Sunderland.—*Quay.*— A sum of £200,000 is to be spent on the construction of a deep-water quay at Sunderland.

Tetbury.- -*Reservoir.*—The U.D.C. proposes to construct a reservoir, estimated to cost £3,000.

Thornaby.—*Houses.*—The Corporation is negotiating for a site on which to build 100 houses.

Tolworth.—*Road.*—The Surrey C.C. proposes to lay a road from Ewell Road to the Kingston by-pass Road.

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TREVOR. — *Houses.* — The Llangollen R.D.C. proposes to erect 20 houses at Trevor and 20 at Trevor Issa.

TROWBRIDGE.—*Road.*—The U.D.C. is considering a scheme for the construction of a road at Trowbridge.

UXBRIDGE.—*Reservoir.*—The Council proposes to erect a reservoir, at an estimated cost of £5,725.

WAKEFIELD.—*Houses.*—The T.C. has applied for a loan of £200,654 for the erection of 366 houses. The Council proposes to erect 1,000 houses during the coming year.

WEETSLADE.—*Houses.*—The U.D.C. proposes to erect 50 houses.

WESTON-SUPER-MARE.— *Concrete Sea Wall.*—The U.D.C. proposes to spend £24,050 on the construction of a reinforced concrete sea wall on the foreshore.

WHITEHAVEN.—*Reservoir.*— A reinforced concrete reservoir is to be constructed at Harras Moor.

WIMBLEDON.—*Terrace.*—The Council proposes to erect a reinforced concrete terrace and châlet at Home Park.

WORTLEY.—*Road.*—The R.D.C. proposes to construct a road from the High Green to Hagmanstone Bar. The cost is estimated at £128,500.

YORK.—*Concrete Bridge.*—The Corporation has submitted to the M.T. plans for the construction of a reinforced concrete bridge over the Ouse at Fulford. The cost is estimated at £56,000.

YORK.—*Houses.*—The Corporation will spend £190,000 on house construction during the coming year, £15,000 on the construction of a road and bridge from Heworth to Monk Road ; and £5,000 on culverting Tang Hall beck.

Tenders Accepted.

BARKING.—*Paving.*—The U.D.C. has accepted the tender of the Patent Victoria Stone Co., Ltd., at 6*s.* 2*d.* per yard, for the supply of 333 yards of artificial stone paving.

BELFAST.—*Concrete Reservoir.*—The T.C. has accepted the tender of Messrs. Logan & Sons, Belfast, at £2,826 11*s.* 4*d.*, for the construction of a reinforced concrete reservoir at Ballyaghagan. Other tenders submitted were : S. R. Boyd, £5,342 6*s.* 5*d.* ; James Henry & Son, £4,842 19*s.* 10*d.* ; J. & R. Thompson, £4,350 ; James Ross & Son, £4,289 16*s.* 5*d.* ; R. D. Pollock, £4,013 13*s.* ; John Graham, £3,978 7*s.* 9*d.* ; W. J. Campbell & Son, £3,948 2*s.* 2*d.* ; J. & W. Stewart, £3,745 14*s.* 7*d.* ; R. Coulhoun, £3,719 5*s.* 1*d.* ; H. Laverty & Sons, Ltd., £3,537 ; Grainger Bros., £3,334 1*s.* ; and McLaughlin & Harvey, £3,250.

BULKINGTON.—*Concrete Water Tower.* —The U.D.C. has accepted the tender of Mr. J. Gray, Coventry, at £3,435, for the construction of a reinforced concrete water tower.

CHESHUNT.—*Concrete Pump Chamber.* —The U.D.C. has accepted the tender of Mr. A. M. Turner, at £681 13*s.* 9*d.*, for the construction of a reinforced concrete pump chamber at the sewage disposal works, at Waltham Cross. Other tenders submitted were : W. & C. French, £1,058 12*s.* 8*d.* ; Engine Foundation & Concrete Contractors, Ltd., £850 11*s.* 1*d.* ; and Saxild and Partners, £833 3*s.* 6*d.*

EASTBOURNE.—*Concrete Foundations.*— The T.C. has accepted the tender of Messrs. Peter Lind & Co., at £476, for foundation work at the power station.

EXETER.—*Concrete Houses.*—The T.C. has accepted the tender of Messrs. John Laing & Son, Ltd., at £449 12*s.* 6*d.* per house, for the construction of 154 concrete houses on the Buddle Lane estate.

GLASGOW.—*Concrete Terracing.*—The T.C. has accepted the tender of Messrs. Brodie, Campbell & Co., at £499, for concrete terracing at Tollcross Park band stand.

GOSPORT.—*Houses.*—The T.C. has accepted the tenders of Messrs. John Laing & Son, Ltd., for the construction of 46 houses at Forton and 144 at Ann's Hill.

LYME REGIS.—*Sea Wall.*—Messrs. F. Bevis, Ltd., of Portsmouth, have secured a contract, at £6,000, for the reconstruction of the sea wall on the Marine Parade.

NELSON.—The T.C. has accepted the tender of Messrs. Matthews & Mumby, Ltd., for reinforced concrete work in connection with the Ridgaling reservoir.

PILFREY, LINCS.—*Concrete Bridge.*— The Lindsey C.C. has accepted the tender of Messrs. K. Holst & Co., £4,750, for the construction of a reinforced concrete bridge at Pilfrey.

ROCHDALE.—*Concrete Raft.*—The T.C. has accepted the tender of Messrs. R. & T. Howarth, Rochdale, for the construction of a reinforced concrete raft for the 'bus garage in Mellor Street.

SCARBOROUGH.—*Concrete Reservoir.*—The T.C. has accepted the tender of Messrs. C. Rearton & Partners, Wolverhampton, at £23,000, for the construction of a reinforced concrete reservoir at Spring Hill.

SKEGNESS.—*Concrete Water Tower.*—The U.D.C. has accepted the tender of the Industrial Constructions, Ltd., at £6,666, for the construction of a reinforced concrete water tower.

TAUNTON.—*Concrete Houses.*—The T.C. has accepted the tender of Messrs. F. & E. Small, Taunton, at £21,837, for the construction of 56 concrete houses on the Lambrook Road site.

WELNEY.—*Bridge.*—The Norfolk C.C. has accepted the tender of Messrs. K. Holst & Co., at £6,350, for the construction of a reinforced concrete bridge at Welney.

WILLESDEN.—*Concrete Houses.*—The U.D.C. has recommended for acceptance the tender of Messrs. Roberts & Co., at £503 per house, for the construction of 100 concrete houses.

Recent Patent Applications.

239,512.—Dr. H. Kupelwieser: Concrete walls.

246,374.—M. Stieler: *In situ* concrete chimneys.

246,383.—T. Spragg and G. Spragg: Concrete-slab walls.

246,626.—D. Jones and G. Creak: Concrete blocks.

246,950.—E. Hurden and A. P. Hurden: Facings for concrete structures.

247,097.—K. P. Billner: Manufacture of cement.

247,244.—A. E. White: Manufacture of concrete tile.

247,257.—H. F. Stalley: Apparatus for lining pipes with cement.

247,499.—Chatwood Safe Co., Ltd., and H. S. Bruckshaw: Reinforced concrete safes.

247,640.—British Reinforced Concrete Engineering Co., Ltd., and E. B. Hall: Reinforcement for road foundations.

247,747.—Diespeker & Co., Ltd., and L. T. Rackham: Mounting doors on concrete structures.

248,282.—U. B. Voisin: Manufacture of aluminous cements.

248,420.—A. W. C. Shelf: Reinforced concrete paving.

248,472.—British Reinforced Concrete Engineering Co., Ltd., and E. B. Hall: Reinforced concrete piles.

248,576.—A. Horten: Concrete pipes.

248,579.—British Reinforced Concrete Engineering Co., Ltd., and E. B. Hall: Reinforcing fabric for concrete road foundations.

248,630.—E. L. Raworth, C. W. Hamilton, T. H. McCall and P. Heard: Reinforcement.

248,815.—C. F. A. Ingerslev: Reinforced concrete blocks and method of lining tunnels.

248,894.—H. L. Lalbert: Concrete blocks and system of reinforced blockwork.

248,937.—H. P. Warren: Concrete buildings and blocks.

249,273.—T. G. Whitmore: *In situ* concrete constructions.

249,294.—J. S. Withers: Shuttering.

New Company Registered.

J. COOKE & SON (HUDDERSFIELD), LTD. (211,873). Registered February 19. To take over the business of concreter, contractor and roofing engineer carried on at Little Royd, Huddersfield, as "John Cooke." Nominal capital, £15,000. Directors: J. T. Cooke, Lyndene, Foxglove Road, Huddersfield (Chairman); L. Cooke, 29, Springdale Avenue, Huddersfield; F. Radcliffe, 190, Trinity Street, Huddersfield.

Change of Address.—The registered office of Messrs. B. & T. Reinforcement, Ltd., has been removed from 39, Victoria Street, S.W.1, to the firm's new works at Wellington Crescent, New Malden, Surrey.

JUN 30 1926

Price 1s. 6d. net. *Annual, Post Free, 18s.*

CONCRETE AND CONSTRUCTIONAL ENGINEERING

JUNE 1926 CONCRETE SERIES Nº1 **VOL. XXI No. 6**

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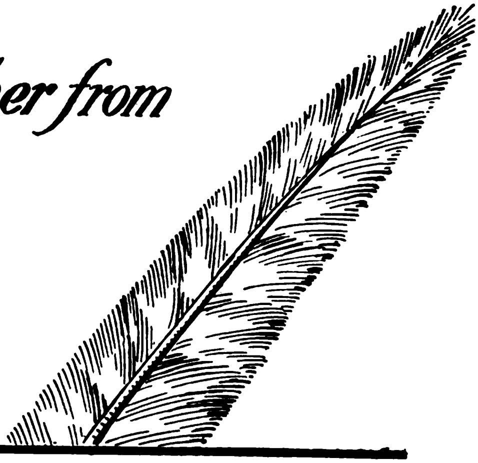
The Third Feather from the Pelican.



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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XXI. No. 6. LONDON, JUNE, 1926.

EDITORIAL NOTES.

Reinforced Concrete Regulations.

UNDER the provisions of the London County Council (General Powers) Act, 1909, the L.C.C. are empowered to make Regulations in respect to the construction of buildings wholly or partly of reinforced concrete, but it is stipulated that notice must be given to the following institutions of any intention on the part of the L.C.C. to apply to the Ministry of Health for allowance of any such Regulations : The Institution of Civil Engineers, Royal Institute of British Architects, Surveyors' Institution, Institution of Structural Engineers.

Early last year certain proposals for the revision of the Regulations approved in 1915 were communicated by the L.C.C. to these institutions, and a Joint Committee, consisting of the following members, was appointed to consider these proposals on behalf of the Institutions : Messrs. W. C. Unwin (Chairman), E. S. Andrews, Chas. A. Daubney, H. J. Deane, Oscar Faber, H. D. Searles-Wood, P. J. Waldram, Dendy Watney. (On the decease of Mr. Daubney last year, Mr. W. H. White was appointed to the Committee.)

As a result, suggestions in connection with the proposed revised Regulations were submitted to the L.C.C. in September last, and these, it is understood, are still receiving consideration. The L.C.C. is now introducing a Bill in Parliament, (General Powers) 1926, in which the power to issue Regulations referred to above is to be extended with respect to the *conversion* of any building or part of a building constructed wholly or partly of reinforced concrete. The Joint Committee have met to discuss the probable effects of the proposed Bill, and as a result, upon their recommendation, the institutions concerned have petitioned against the Bill. The Bill, which is being promoted in the House of Lords, has been referred to a Standing Committee, and the latter is now hearing evidence in connection with the petitions.

The Bowstring Girder in Reinforced Concrete.

THERE are two different classes of bowstring girders, one with triangulated bracing and the other without diagonal members. The latter is peculiarly suited to construction in reinforced concrete, which effects a rigid junction between the members meeting at a point, and it is only logical to take advantage of this monolithic property of the material. If joints are introduced in order to make the girder fit certain methods of calculation, the stiffness of the girder is reduced; the cost is increased by using hinges, and a part of the inherent stiffness of the material is neglected.

The majority of girders of the bowstring type which have been constructed in reinforced concrete are without hinges at the joints. The three equations of statics and the expressions for the linear and angular displacements at each section are sufficient to calculate the stresses in the girder. The method of calculation of such girders, writes M. E. Balis in *Le Constructeur de Ciment Armé*, is due to Professor Vierendeel, of Louvain University, who introduced this type of bridge twenty-seven years ago. Experiment has proved that the stresses created in the girder correspond closely with the calculated stresses. One bridge was tested to destruction by Belgian engineers at Tervueren. Certain engineers hold the opinion that the vertical members are in simple tension and that the stresses can be calculated by the so-called "classical method," but a member which is placed between a top chord which shortens and bends and a bottom one which lengthens can hardly be in tension only.

The following interesting particulars of reinforced concrete bowstring girders of the Vierendeel type are given in the article in our contemporary: At La Louvière, a footbridge 182 ft. in span; at Tournai, a road and railway bridge with a central span of 101 ft. and two 50-ft. side spans; at Escanaffles, a road and railway bridge of 133-ft. span; at Kain, a road bridge of 130-ft. span; at Boisin, a road bridge of 55-ft. span; at Bleharies, a road bridge of 130-ft. span. These bridges are without cracks or other defects, and have a mean deflection of 0·009 of the span. Those which have been calculated by the simpler and inaccurate method invariably show cracks at the verticals, which will reduce the lives of these structures as oxidation of the metal progresses. Tests on these bridges have also shown their greater sensibility to vibration compared with the Vierendeel Girders.

Scientific Concreting.

For some years we have been familiar with the research work undertaken in the United States on the manufacture of concrete, but we think the average contractor will be somewhat surprised to learn from the article by Mr. A. E. Wynn in this issue how far these experiments have been applied in practice. The practice which is rapidly extending in America is to throw on the contractor the responsibility of making concrete to a specified strength without being told what proportions of cement and fine and coarse aggregate to use, and this appears to be working out satisfactorily from the points of view of all concerned. The practice is based on the fact, proved by experiment, that the strength of concrete depends solely on the proportion of mixing water to cement, and that strength can be specified by stating the amount of water to be used per bag of cement irrespective of any other factor providing sound materials are used. Once the proportion of water to cement is specified, the composition of the concrete will be controlled by its workability only; obviously aggregate cannot be added indefinitely with the object of cheapening the concrete, for above a certain proportion it would be too stiff to flow. The "cement–water" ratio method of specifying concrete strengths and much more information on up-to-date American concrete practice, is fully explained in Mr. Wynn's valuable article.

Controlling the Manufacture of Concrete to obtain Uniformity of Strength.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

THE manufacture of concrete has long been a more or less haphazard process, always considered unsatisfactory but endured for want of better methods. It is only during the past three or four years that any attempt has been made to put it on a scientific basis. This is due to the fact that we have never rightly understood the parts played by the various constituent materials, so that until recently there has been no incentive to develop methods of controlling the manufacture. Now that we know the essential requirements for obtaining concrete of a uniform pre-determined strength, the development of methods to obtain this result is a natural consequence.

With the theoretical knowledge and the practical means of applying this knowledge available, there is no longer any excuse for adhering to the old and uncertain methods of manufacture. The results of experiments covering several years and made by independent investigators have established the relative importance of the cement, aggregates, and water, especially the latter, and have taught us how they should be proportioned in order to obtain a concrete of a uniform pre-determined strength.

The best known of these experiments are those carried out by Mr. Duff A. Abrams, of the Lewis Institute, Chicago. His deductions and recommendations are now accepted throughout the United States, and are probably familiar to all engineers engaged in concrete design and construction, as mention of them has been made from time to time in this Journal. Engineers will not, therefore, be wholly unfamiliar with the terms " water-cement ratio," " slump test," " fineness modulus," etc.

The purpose of this article is to show how the theory involving these terms is put into practice on the job under actual construction conditions. Many engineers may be under the impression that the theory is all right but that it is only suitable for the laboratory, and that they still have to be shown how field methods can be improved. This we will attempt to do.

As a result of recent knowledge, the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete in their Report recommended that a concrete of the desired strength be specified instead of stating definite and arbitrary proportions. This suggested radical change naturally gave an impetus to investigations of field methods to determine whether it would be popular with the average contractor.

This suggestion was a step in the right direction, since the engineer and architect are mainly concerned with obtaining a concrete that will be uniform and have the strength required, and not with the methods the contractor may use to obtain these results. It, however, threw the burden on the contractor and he was naturally sceptical as to whether it could be put into practice without undue hardship to him and increased cost. If he could see where he benefited he would be willing to try it.

Some of the larger contractors, on their own initiative and in co-operation with the engineers, tried out " field control " methods on their work and compared the results and cost obtained with those obtained by the old methods. The results were so satisfactory that the use of control methods is rapidly extending throughout the country, and on important work at any rate it is now universal practice. Let us first see why and where there is need for better methods in the manufacture of concrete.

Need for Improvement.

Probably the main objection to concrete, on the part of architects in particular, has been that although they approved of the material in general the quality of the concrete produced on the job was always in doubt since there were no adequate means of controlling the manufacture to produce a uniform product of assured quality. That there was some justification for this is obvious when we consider that samples of concrete may vary 60 per cent. to 70 per cent. or more in strength on the same job. One factor alone—the quantity of water used—can cause this variation.

Consequently, specified unit stresses have always been placed at a low figure, allowing a big margin of safety even with a low ultimate strength. For instance, 650 lbs. per sq. in. is allowed for the maximum extreme fibre stress in bending, based on 32½ per cent. of a strength at 28 days of 2,000 lbs. per sq. in., giving a factor of safety of about 3. Job concrete as manufactured in the old way will often fall in strength to 1,600 lbs. per sq. in., giving a factor of safety of 2½, which is still safe and is the later figure suggested by the Joint Committee. If now with field control methods we can guarantee a strength of 2,000 lbs. without increased cost we could safely use a stress in design of 800 lbs. per sq. in., and this is still conservative because higher strength can be guaranteed.

The only way to obtain specified higher unit stresses is for engineers and contractors to prove that they can consistently produce concrete which will have a uniform strength. Then it will be possible to design structures using the material to the fullest advantage instead of with the great waste that is now necessary because of the uncertain methods of proportioning and mixing on the job and the consequent lack of uniformity.

Eliminating the causes for the variations in strength will place concrete on the same plane as other structural materials of definite strength, resulting in an increased confidence in its use. The usual method of specifying concrete is by arbitrary proportions of cement and fine and coarse aggregate, with little or no mention of the amount of water to be used. It has long been known that this method results in concrete of varying strength, although mixed in the same proportions, but the method has existed for want of better knowledge and because it is easy and has given fair results in the past.

The results have been fairly satisfactory, however, only because unit stresses used have been so low that there is always a good margin of safety even with the poorest of concrete. Arbitrary proportions do not take into account the voids or grading or sizes of the aggregate. No two samples of aggregates have exactly the same properties, and therefore standard results cannot be obtained by mixing any fine and any coarse aggregate in the same proportions. Even if the specified proportions are correct, the usual wheel-barrow method of measurement is far from accurate, and at the best is guesswork. The labourer will usually wheel as little as possible ; on the other hand, some contractors will try to load on all the wheel-barrows will hold.

Also, specified proportions are based on dry compact aggregate, while in practice they will always be measured loose and will contain some moisture, especially the sand. A rainy day will thoroughly soak the sand, and it will retain the moisture for a long time. Wet sand will bulk or increase its volume as much as 30 per cent. with a moisture content of only 5 per cent. by weight. A wheel-barrow of sand may then contain any amount, depending on the ideas of the labourer filling it and on the moisture content. Coarse aggregate will also bulk when wet, but to a much smaller amount.

Constant supervision will not do much to change these conditions. Therefore an engineer specifying a concrete to be mixed, say, in the proportions of 1 : 2 : 4 is first of all assuming that the properties of the aggregates will be such that these are the best proportions to use ; second, that they will be perfectly dry ; and, third, that the proportions will be constantly maintained on the job. Actually he will be getting a concrete that may be mixed in the proportions of 1 : 1 : 2, 1 : 4 : 9, or in any one of an indefinite number of combinations, with a corresponding variation in strength.

Perhaps, unfortunately for the betterment of the industry, the cement is relied upon to bear all the burden of producing a concrete that will give sufficient margin of safety over the assumed stresses, which it generally will do since these stresses are so low. Owing to the attention always given to " cement " instead of to " concrete," the former has reached a high state of perfection while the latter, of which it is only one ingredient, has improved hardly at all and only by the improvement in cement.

It is commonly stated that concrete structures will last for ever and improve with age—and they should do so ; but it is not true unless the same care is taken with proportioning, mixing, and curing as is taken in the manufacture of cement.

We have said nothing yet about proportioning of the water. This is rarely specified, and is usually left to " the man on the mixer," who must have unknowingly governed the strength of many a structure. We now know the great importance of regulating the amount of water used in mixing, and that in fact, other things being equal, the quantity of water will govern the strength obtained. How many engineers have carefully watched the cement go into each batch, and at the same time allowed the contractor to flood the mixture with water ? Far better to have watched the water and left the cement alone ! Excess water can easily reduce the strength of concrete 50 per cent. Unfortunately water is the cheapest ingredient, so the least attention is usually paid to it.

Considering together all the factors which go to the making of concrete, we can see how difficult or impossible it is to produce a guaranteed and uniform strength without some means of " field control." Uniformity in strength is what induces confidence and should be the main object in view ; at the same time, with uniformity will go increased strength.

To attain this result two things are necessary—first, to design the concrete mixture for the strength required ; second, to control the manufacture so that the designed proportions can be closely and uniformly maintained.

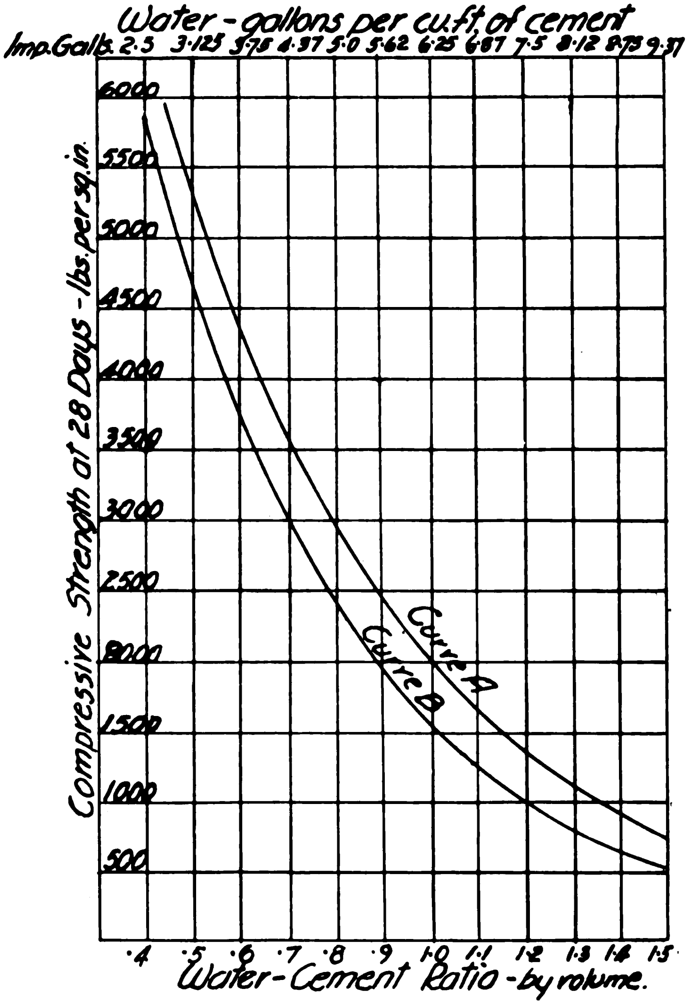

Fig. 1. RELATION BETWEEN WATER-CEMENT RATIO AND STRENGTH.

General Principles of Design.

The design of concrete mixtures is based on the water-cement ratio theory. This is, that for given materials and conditions of manipulation the strength of concrete depends on the ratio of the volume of mixing water to the volume of cement so long as a workable consistency is obtained.

Another way of stating the theory is that so long as the water bears a constant ratio to the cement the strength of the concrete at a given age is fixed, regardless of the quantity of aggregate added, so long as the mixture is plastic and workable and the aggregate clean, sound, and durable.

Two things will be noticed. Strength depends on the ratio of water to cement only, while economy of the concrete depends on the amount of aggregate that can be added and still have a workable mixture, and this latter depends on the sizes and grading of the particles. Increasing the amount of aggregate will increase the volume or yield of the concrete produced for a given amount of cement and water. It is thus to the advantage of the contractor to design his concrete mixtures, for by so doing he can use the minimum amount of cement without sacrificing strength.

The amount of water used in the mix being the controlling feature of strength, changing the amount of cement, the degree of plasticity of the concrete, and the size and grading of the aggregates only affect the strength through changing the amount of water required in the mix.

The lower the water-cement ratio the greater will be the strength as long as the mixture is workable.

Fig. 1 shows the relation between the water-cement ratio and the strength of concrete at 28 days. The upper curve *A* is for average conditions where the field operations are under control, and the lower curve *B* indicates the minimum strength to be expected when the operations are not under rigid control. It will be seen that they give strengths varying by about 500 lbs. per sq. in.

Mixing drier concrete, adding cement, and using coarser aggregate, all decrease the amount of water required and so increase the strength. It is necessary to understand the influence of each of these factors on the water-cement ratio and the manner in which they are measured.

Consistency of Concrete.

The consistency is the degree of workability. It used to be defined by the terms "dry," "wet," "quaking," "plastic," "sloppy," etc. All these vague terms are now replaced by specifying that the concrete must have a certain "slump," the amount of which will vary with the purpose for which the concrete is to be used.

The slump is the amount of settlement in inches obtained after filling a standard metal cone form of 4 in. top diameter, 8 in. bottom diameter, and 12 in. high, and then removing the form. The less the slump and consequently the stiffer the mixture—provided that it is workable—the stronger will be the concrete, other conditions being equal.

Maximum strength cannot be obtained, as the mixture would be too stiff to work, but 70 per cent. to 90 per cent. is obtainable. Mass concrete and pavements can be poured stiffer than reinforced concrete and thin sections, and so require a smaller slump.

A concrete giving a slump of ½ in. to 1 in. will contain only a little more water than is required for maximum strength, but it will be too stiff to work. An addition of 10 per cent. more water will give a slump of 3 in. to 4 in. and will reduce the strength to about 90 per cent. of the maximum obtainable. An addition of 25 per cent. more water will increase the slump to 6 in. or 7 in. and reduce the strength to about 75 per cent. of the maximum, while 50 per cent. more water will give a slump of 8 in. to 10 in. and reduce the strength to 40 or 50 per cent. of the maximum. The smallest slump that will give a consistency suitable for the work in hand should be used. A slump greater than 6 in. to 7 in. is seldom required.

The recommended values for the slump are: For mass concrete, 2 in.; for concrete roads, 2 in.; for reinforced concrete in comparatively thin sections, as in buildings, 6 in. to 7 in.; in heavy sections, 2 in. to 4 in.; for mortar floor finish, 2 in. The water required to produce a certain slump depends on the proportions of the mix and the sizes and grading of the aggregate.

Quantity of Cement.

The commonest method of increasing the strength of concrete is to add cement. But increased strength is not necessarily obtained unless the consistency remains the same. If the consistency is the same then obviously less water is used per cubic foot of cement, and hence the water-cement ratio is lower.

Another way of looking at it is to keep the cement constant and reduce the aggregate, thereby making a richer mix; then the smaller volume of aggregate will require less water for the same consistency. The addition of cement thus only increases the strength in so far as it reduces the ratio of mixing water required. Cement is measured by its relation in volume to the aggregate, the unit of measurement being the cubic foot = 94 lbs.

In designing mixtures three terms are used to define the proportions, namely the "field mix," the "nominal mix," and the "real mix." The "field mix" indicates the proportions of aggregate in terms of damp loose volumes as measured on the job. As aggregate on the job generally contains varying amounts of moisture the actual amount of dry aggregate in a given volume will vary. In order to have a standard basis of reference for measurement, aggregates are assumed to be dry and rodded. Proportions in terms of dry rodded segregated volumes of material are called the "nominal mix."

There is still a variable, and that is the proportion of fine to coarse aggregate, so that the best way of expressing the proportions is by the "real mix," or the proportion of cement to a volume of mixed and dry aggregates. A real mix of, say, 1 : 4·5 may be a nominal mix of 1 : 1·6 : 3·7 and a field mix of 1 : 2 : 4.

Aggregates.

It is assumed that aggregates are clean, durable, structurally sound, and free from coatings and organic matter. The grading and maximum size of the aggregate have an important effect on the strength of the concrete, because they govern the amount of mixing water required for a given consistency and hence the water-cement ratio.

Assuming a certain proportion of cement to total volume of mixed aggregate (the "real mix") and a certain consistency (the slump), the better the aggregate is graded the less will be the voids and the mortar required, and hence the lower the water-cement ratio and the greater the strength. Or to maintain the same strength with the same consistency, the better graded the aggregate the less the mortar required and the smaller quantity of cement necessary. Also, the larger the particles—that is, the coarser the grading—the less will be the amount of water required and the greater the strength, provided the particles are not too coarse for the amount of cement used.

Fineness Modulus.—The grading of an aggregate is defined by its "fineness modulus," as determined by the sieve test. The standard sizes of sieves used for determining the modulus are numbers 100, 50, 30, 16, 8, 4, ⅜, ¾ and 1½, each one having a clear opening twice the size of the preceding one. The "fineness modulus" is the sum of the percentages of the amounts coarser than each sieve to the total volume or weight of the sample divided by 100.

Different mixtures of aggregates with the same fineness modulus require the same amount of mixing water for a given consistency, and will therefore produce the same strength, other conditions being equal and as long as the concrete is workable. The coarser the aggregate the higher the fineness modulus, the limit that can be used being reached when the concrete becomes too harsh to work with a given ratio of cement to aggregate.

Knowing the fineness modulus of both a fine and coarse aggregate, the proportions in which to mix them to give a required fineness modulus for the mixed aggregate can be calculated as follows:

If M = fineness modulus of the mixed aggregate
M_f = ,, ,, ,, ,, fine ,,
M_c = ,, ,, ,, ,, coarse ,,
r = ratio of volume of fine aggregate to sum of volumes of fine and coarse aggregate measured separately

then $M = rM_f + (1 - r) M_c$ and $r = \dfrac{M_c - M}{M_c - M_f}$.

It is necessary also to know the limits of sizes into which the aggregate is graded. For this purpose 1 in. and 2 in. sieves are included in addition to those used for finding the modulus. The maximum size is the next largest size to that sieve which will retain at least 15 per cent.; that is, if 15 to 16 per cent. were retained on the ⅜ sieve the maximum size would be ¾, and if only 14 per cent. were retained the maximum size would be ⅜. The finest size is that sieve through which not more than 15 per cent. will pass.

A sand is said to be graded from zero to the maximum size, so also is a mixture of fine and coarse aggregate. The best combinations of fine and coarse to use are those giving the highest fineness moduli, providing the concrete is workable.

Fig. 2 gives these best or maximum values of the fineness modulus. This table is for sand and gravel (round pebbles). If crushed stone, slag, or flat pebbles are used for the coarse aggregate, these values should be reduced by 0·25, because rounded particles will pack better with less mixing water. When certain volumes of fine and coarse aggregate are mixed together, the resulting volume will be less than the sum of the separated volumes. For ordinary combinations the shrinkage will average closely to one-eighth, so that a "nominal mix" of 1 : 2 : 4 will give a "real mix" of about 1 : 5·25.

Fig. 2. Maximum Permissible Values for Fineness Modulus of Aggregates.

Real Mix	Size of Aggregates								
Cem. to Aggr.	0-8	0-4	0-⅜"	0-¾"	0-1"	0-1½"	0-2"	0-3"	0-6"
1:9	2.45	3.05	3.85	4.65	5.00	5.40	5.80	6.25	7.05
1:7	2.55	3.20	3.95	4.75	5.15	5.55	5.95	6.40	7.20
1:6	2.65	3.30	4.05	4.85	5.25	5.65	6.05	6.50	7.30
1:5	2.75	3.45	4.20	5.00	5.40	5.80	6.20	6.60	7.45
1:4	2.90	3.60	4.40	5.20	5.60	6.00	6.40	6.85	7.65
1:3	3.10	3.90	4.70	5.50	5.90	6.30	6.70	7.15	8.00
1:2	3.40	4.20	5.05	5.90	6.30	6.70	7.10	7.55	8.40
1:1	3.80	4.75	5.60	6.50	6.90	7.35	7.75	8.20	9.10

This Table is for sand and gravel aggregate. For mixes not given use values for next leaner mix. For crushed stone or slag, reduce values by 0·25 per cent. For pebbles consisting of flat particles, reduce values by 0·25 per cent. In mass work where smallest dimension is greater than 10 times the maximum size of the coarse aggregate, add for ¾ in., 0·10 per cent.; for 1½ in., 0·20 per cent.; for 3 in., 0·30 per cent.; for 6 in., 0·40 per cent.

The lowest desirable fineness modulus for sand is 1·50.

Maximum value of fineness modulus for sand or screenings not greater than permitted for mortar concrete of same mix.

Water Contained in Aggregate.

The bulking of sand that contains moisture is one of the most variable factors entering into the manufacture of concrete. It results in under-sanded and over-wet concrete. Most sand will contain 2 to 5 per cent. of moisture, which will increase the volume 15 to 30 per cent. or even 40 per cent. Coarse aggregate may contain 2 per cent. of moisture but will not bulk to any extent. Also, aggregates will absorb water up to about 1 per cent. by weight.

Obviously when calculating the proportions to be used on the job—the " field mix "—allowances must be made for water content, absorption, and bulking. The effect of these can be determined by simple experiments on the job—or a fairly close assumption is that sand will contain 3 per cent. of moisture and stone 1 to 2 per cent. (except after rain when for sand this should be increased to 6 per cent.), and that absorption will be 1 per cent. for each, if the aggregate is dry. From the amount of water required by the water-cement ratio there must be deducted the amount already contained in the aggregate, if wet; and the amount required for absorption, if dry, must be added to obtain the correct quantity to add to the mix.

The bulking of sand increases with the percentage of moisture up to a certain amount—about 5 or 6 per cent.—after which if more water is added the volume of sand will decrease until when it is fully saturated it will have the same volume as when perfectly dry and rodded. This property of sand is important, and as will be seen later, is made use of in the method of measuring sand by the " sand inundator."

Inter-relation of the Factors Governing Strength.

The water-cement ratio is the factor that governs strength, but the consistency, mix, and grading of the aggregates govern the water-cement ratio. The relation between these factors and the strength of the concrete is shown in *Fig.* 3, based on the relation between strength and quantity of mixing water as shown by *Curve B*, *Fig.* 1. It will be seen that the strength of the concrete will increase when the mix and grading of the aggregate are constant and the slump decreases, when the slump and grading are constant and the proportion of cement to aggregate increases, and when the slump and mix are constant and the grading or fineness modulus increases. In each case the effect is to decrease the amount of water required per cubic foot of cement.

When this figure is used in designing for controlled concrete, use the strength obtained from *Curve B*, *Fig.* 1 equivalent to the desired strength on *Curve A*, with the same water-cement ratio.

Methods of Designing Mixtures.

The problem of designing concrete mixtures consists in determining first the ratio of water to cement that will produce a concrete of the desired strength; second, to determine what will be the most economical proportion of cement to aggregate with the material available, with the provision that the concrete will be workable and of a suitable consistency for the work in hand.

The strength required is specified, and this fixes the water-cement ratio which can be obtained from *Fig.* 1. *Curve A* gives the strengths that will be obtained under average conditions where the concreting operations are under control, while *Curve B* gives the minimum strengths that may be expected when the job operations are not under strict control; in other words, 500 lbs. per sq. in. represents the average difference in strength that may be expected between controlled and uncontrolled concrete. With mechanical means of controlling the aggregate and water, *Curve A* should be used.

These curves are based on using good average material. If very fine or very coarse sand has to be used the true water-cement ratio curve should be found experimentally, as will be described later. Also, on a job involving a large yardage of concrete, determining the curve for the job in question with the materials that will be used may result in economy, since higher strengths may be found than are given by *Curve A*.

The consistency should always be the driest that can be used for the purpose required. As the slump is a measure of consistency, it should be specified for various parts of the work.

The proportioning of the cement to aggregate can be done in various ways, the aim being to find the largest volume of aggregate that can be used with a fixed quantity of cement and water to give a certain consistency. An easy method is by using the fineness moduli of the aggregate, which requires a small testing outfit. If this method is too technical for the average contractor the same result can be

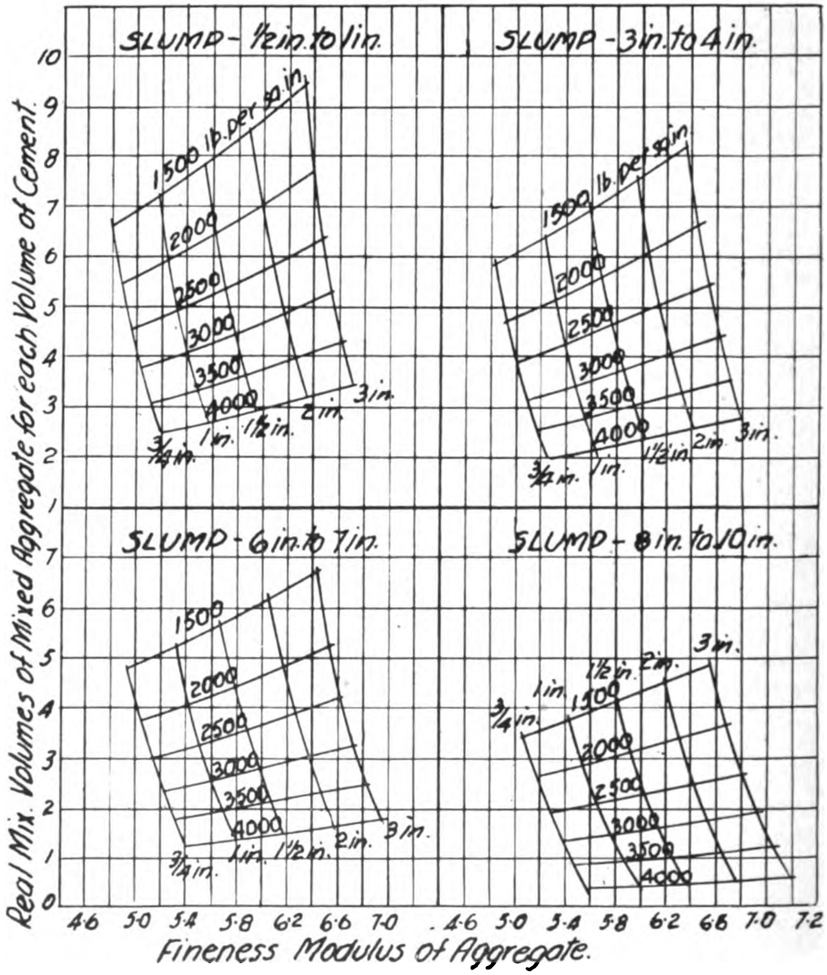

Fig. 3. RELATION BETWEEN VARIOUS FACTORS AND STRENGTH.

found by trial, though the same degree of economy cannot be reached as with the former method.

Whether the most economical proportions or not are used, the strength will be uniform so long as the water-cement ratio is not changed and the mixture is workable, and this is the main aim from an engineering view-point.

(*To be continued.*)

Testing Cement and Concrete.*

This is the fourth edition of "Standard Methods for the Testing and Analysis of Cements," first published in 1904, and gains considerably in usefulness to the concrete industry by the inclusion of the chapter on concrete making. An Introduction gives an outline of the history of this well-known firm of Portland cement manufacturers, which was in existence as makers of Roman cement many years before Portland cement was invented in 1824. The growth of the business is shown by the fact that the weekly output of Portland cement has grown from 172 tons a week in 1879 to 8,000 tons a week this year, including rapid-hardening Portland cement. Remarkable as is this growth in production, at least one man, Mr. Fred Gibson, now a Director and Secretary of the Company, has witnessed practically the whole of it, having entered the service of the firm in 1885 and acted as Secretary since 1894.

Following a chapter on the manufacture of Portland cement, in which the modern processes and plant used at Wilmington are fully described and illustrated, is a valuable chapter on cement testing. This subject is dealt with in a novel manner. The British Standard Specification for Portland Cement (1925 edition) is given in full, with explanatory notes where necessary and illustrations to make clear the methods.

The advantages and possibilities of rapid-hardening Portland cement are clearly set out in a separate chapter, and then is given a great deal of useful information on the best methods for, and precautions to be taken in, the production of good concrete, in the compilation of which use has been made of reports of American investigators. In some notes emphasising the importance of using clean aggregates, an interesting case of the danger attending the use of inferior material is given: "A remarkable experience was obtained during the building of some filter beds in connection with a well-known water supply scheme. The concrete was being laid on the top of a hill, and in this exposed position it cracked, often within an hour or two of being laid. These cracks appeared while one watched them, and considerable time and trouble were expended in investigating the cause. It was at first thought the trouble was due to the rapid drying out under the influence of strong winds, but it was found that the cracks could not be created when testing comparatively small pieces of concrete under severe conditions of wind and sun. The cement itself was thoroughly tested, and found to be perfect in every respect. Eventually the cause was found to be the sand, and when this was washed absolutely perfect concrete was obtained. The theory evolved from this experience was that the sandstone, which came from an old quarry, was in a state of disintegration, and the decomposition liberated a certain amount of kaolin, which contracted rapidly under the quick-drying conditions, thus causing the green concrete to crack."

This chapter is excellent in every respect, and would be of service to the industry if reprinted by itself and published at a low price so as to be in the hands of everyone who uses concrete in quantities however small.

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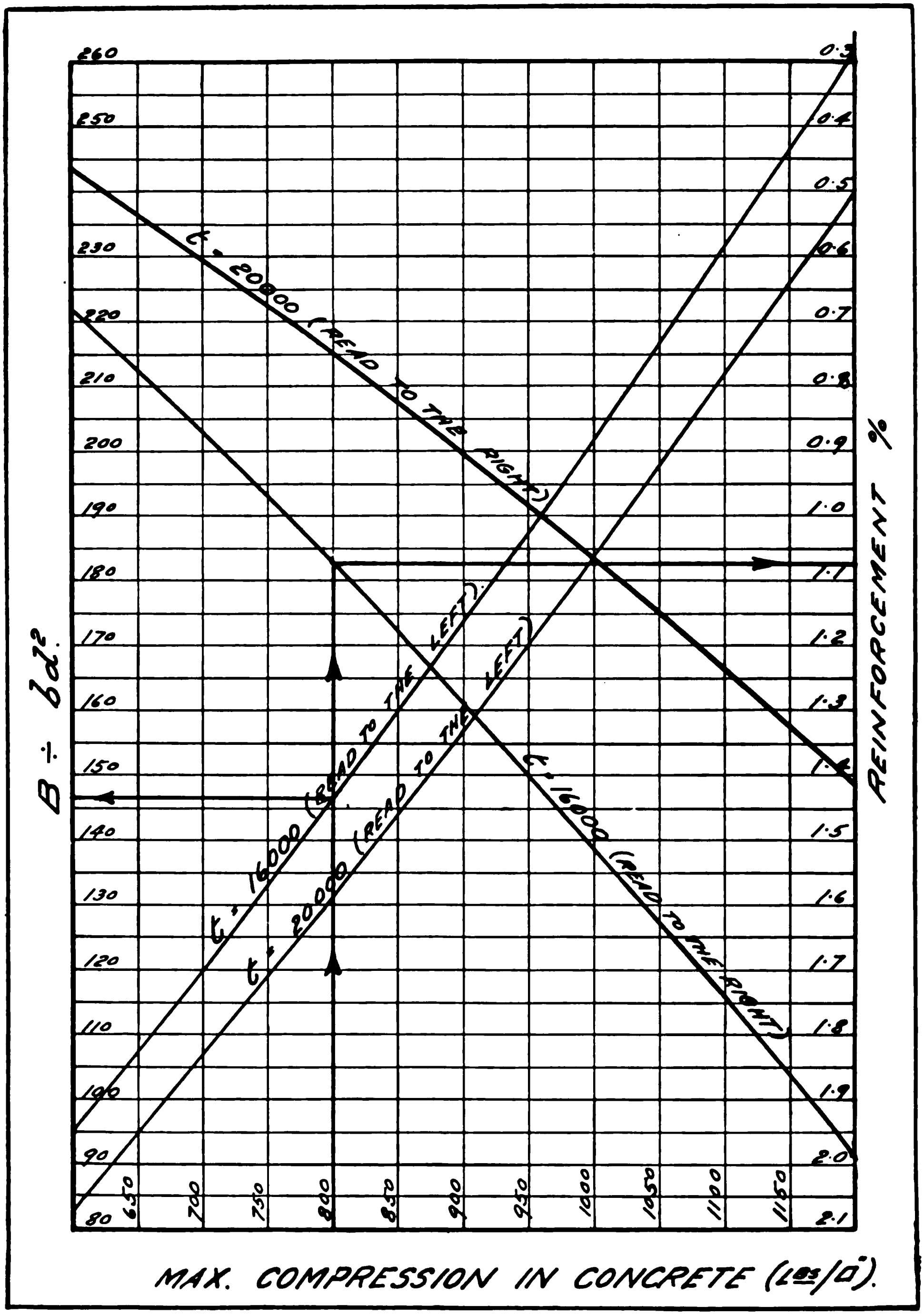
* *The Making and Testing of Portland Cement and Concrete.* (G. and T. Earle (1925), Ltd., Wilmington, Hull. 110 + xix pp. 67 illus. Price 10s.)



Design of Reinforced Concrete Beams and Slabs for High-Strength Concrete. (*See p.* 425.)

The Design of Reinforced Concrete Beams and Slabs for High-Strength Concrete.

By **EWART S. ANDREWS, B.Sc.Eng., A.M.Inst.C.E., M.I.Struct.E.**

GREAT improvements in the strength of concrete have taken place in recent years, and it is now quite easy to obtain concrete of the usual mix which will give strengths well over 5,000 lbs. per sq. in. at three months. This figure relates to test results made upon blocks which were made from the concrete on the job as it came out of the machine mixer, and not to special laboratory-made cubes; it relates also to concrete made from best quality Portland cement, and not to that made from the special aluminous cements which give still higher results. When we remember that the standard design figure of 600 lbs. per sq. in. in compression for concrete, as given in the L.C.C. Regulations and other specifications, is based upon a strength of only 2,400 lbs. per sq. in. at three months, we must realise that it is sheer folly and culpable waste of material to continue to design on these low stresses in cases in which care is taken to ensure high strength of the concrete.

In order to facilitate the design of beams and slabs when higher stresses are employed, the accompanying diagram has been prepared. The diagram relates to the condition in which the specified stresses in the steel and concrete are reached simultaneously—this occurring at the percentage of reinforcement which is commonly referred to as the "economic percentage."

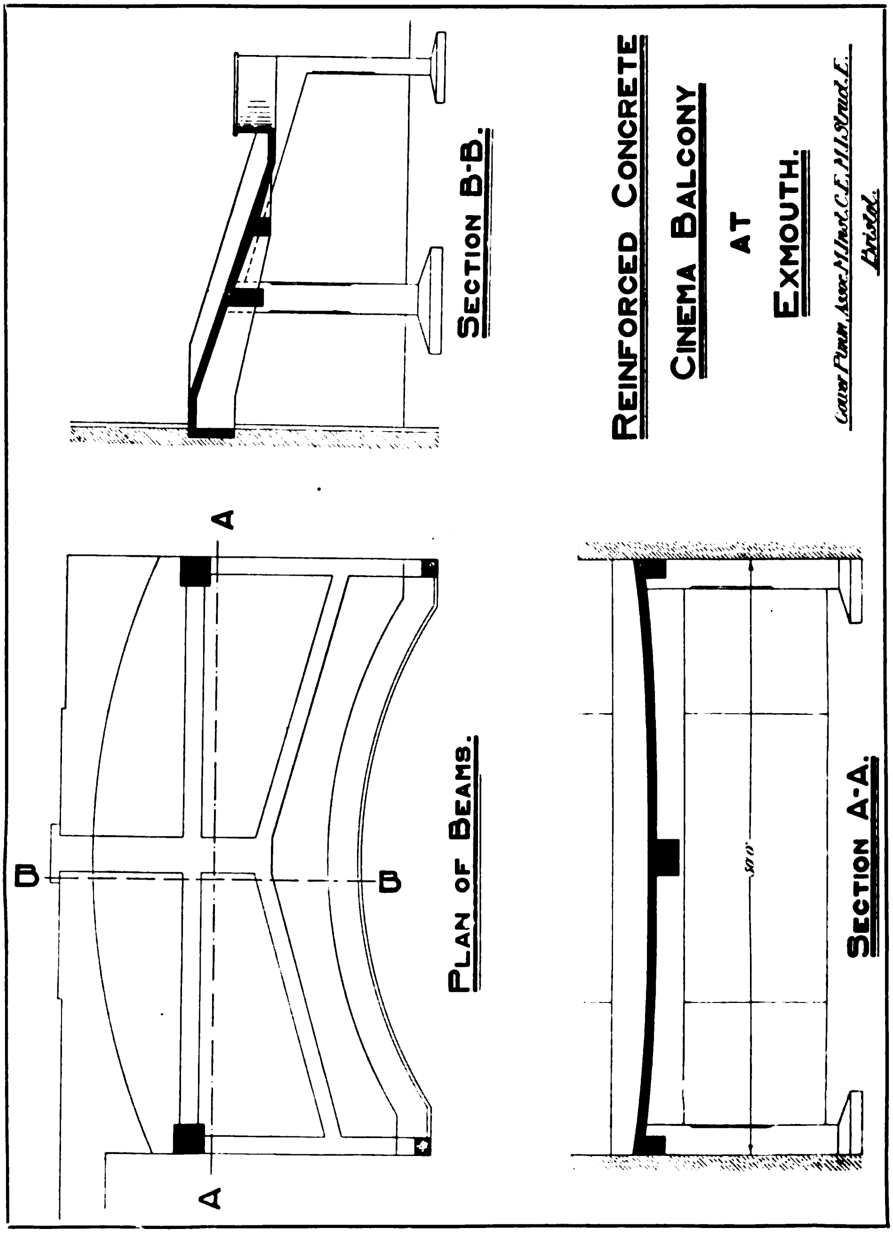
Two sets of curves are given; one corresponding to a tensile stress in the steel of 16,000 lbs. per sq. in. and the other to 20,000 lbs. per sq. in. The horizontal divisions of the diagram correspond to the maximum compression stress in the concrete (lbs. per sq. in.); the left-hand vertical scale gives values of the bending moment coefficient $B \div bd^2$, and the right-hand vertical scale gives values of the percentage reinforcement.

Two sets of curves are shown; those sloping upwards correspond to the left-hand scale of bending moment coefficients, while those sloping downwards correspond to the right-hand scale of percentage reinforcements.

Lines with arrow heads are shown on the diagram corresponding to a maximum compressive strength of 800 lbs. per sq. in., and a steel stress of 16,000 lbs. per sq. in. We move upward until we meet the curve marked "$t = 16{,}000$ (read to the left)" and then run out horizontally to the left, obtaining a value $B \div bd^2 = 147$; we then continue moving upwards until we meet the curve marked "$t = 16{,}000$ (read to the right)" and then move out horizontally to the right, obtaining a percentage reinforcement of 1·08.

We thus know that the permissible bending moment in inch pounds for a beam of breadth b inches and effective depth d inches is $147\ bd^2$ and that the requisite area of steel is $\frac{1{\cdot}08\ bd}{100}$ square inches.

In making the calculations upon which this diagram is based we have assumed the usual "no-tension straight line" rule to hold, and have assumed the modular ratio to be 15. It is true that there is experimental evidence in favour of the view that the modular ratio becomes less as the compressive stress is increased, but there are other considerations, not taken into account in the simple formula for beam stresses, which tend in the opposite direction, and most authorities are, we believe, agreed that satisfactory results are obtained by assuming a constant value for the modular ratio within the range of stresses for which the diagram is drawn.



Reinforced Concrete Balcony at Exmouth. (*See p.* 427.)

Reinforced Concrete Cinema Balcony at Exmouth.

By GOWER PIMM, A.M.Inst.C.E., M.I.Struct.E.

THE construction of the new balcony of the Public Hall Cinema at Exmouth furnishes a striking example of the use of rapid-hardening Portland cement for work of this kind in which speed of erection is often, as it was in the present case, a factor of first importance. The contractors were given possession of the back portion, over which the balcony was to be erected, on March 8, and on April 19 the last of the props was removed from under the completed structure, which was constructed entirely *in situ* between those dates.

The depth of the balcony from back to front is 31 ft. at the sides and 25 ft. at the centre, and the clear width 50 ft. The main support is a heavy reinforced concrete beam of 50-ft. span carried on two massive wall-columns. This beam forms the forward support of a single central cantilever anchored into the back wall and supporting at its front end the ends of two diagonal beams, the other ends of which bear upon two further wall columns, and which support the front portion of the balcony. The floor of the structure is of reinforced concrete, upon which the steps are formed in timber. The balustrade and the stairs giving access to the balcony are also of reinforced concrete.

The rapid construction was made possible, first, as stated, by the use of rapid-hardening Portland cement; second, by the adoption of a simple straightforward design, and third by efficient organisation and close co-ordination between the contractors and the engineer.

Prior to possession of the hall being given to the contractors exact profiles were made of the underside of the slab, and props prepared of correct lengths so that when the latter were erected and the profiles laid upon them the fixing of the reinforcement and the placing of the concrete could be commenced immediately. Profiles were placed at each side of all beams, of which they formed the actual side shuttering, others being placed intermediately to support the slab shuttering. The preparation of the details of these profiles was an intricate matter owing to the fact that the slab was not only cup-shaped but also varied in thickness at different points, and the tops of the profiles took the most unexpected forms; but the office work entailed was amply repaid by the resulting ease and accuracy in erection of the formwork and the remarkably short time in which a true outline of the structure sprang into existence.

The architect is Mr. J. A. Lucas, F.R.I.B.A., the work being carried out by Messrs. Cooper & Son, of Exmouth. The reinforced concrete work was designed by the writer, who also advised upon the organisation of the work and superintended the construction. Much credit is also due to Mr. Lomax and Mr. Wells, to whose efficient handling of the local labour available the success of the work was largely due, and to Mr. Eddie Hutton, chief assistant to the writer, who was responsible for the details.

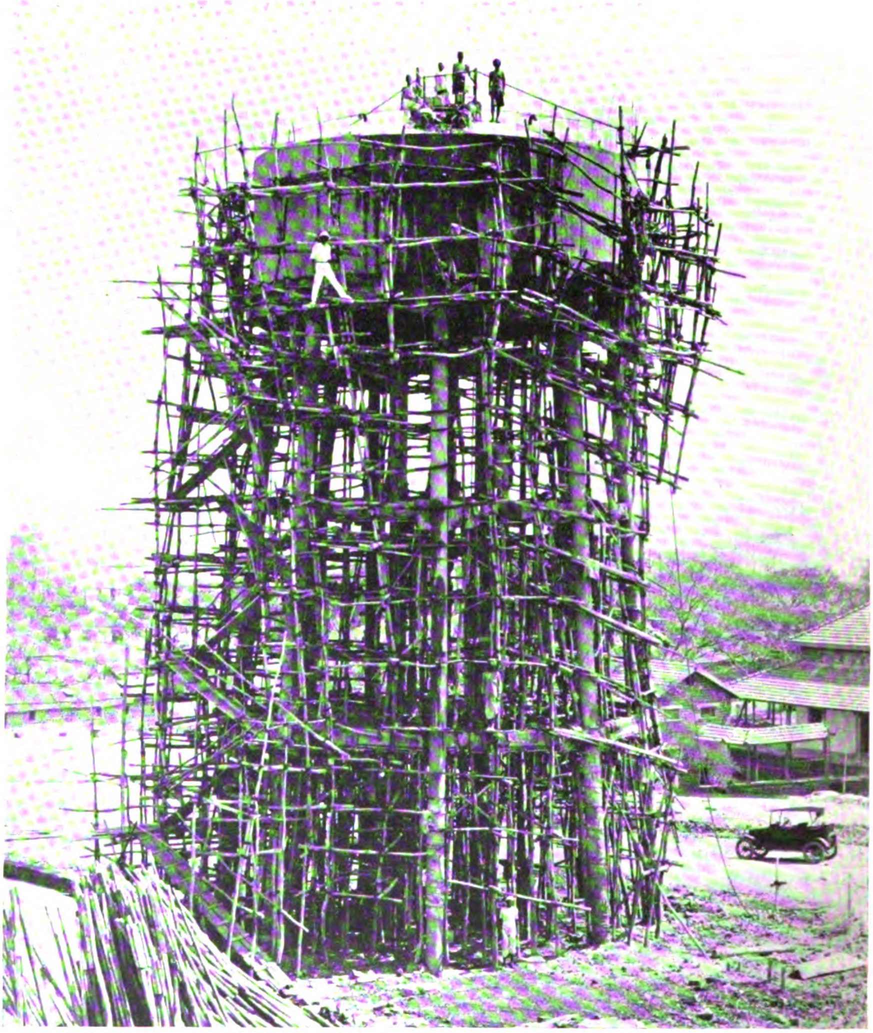


Fig. 1.—Reinforced Concrete Water Tower in India. (*See p.* 429.)

Reinforced Concrete Water Towers in India.

By R. P. MEARS, M.Inst.C.E.

THE water tower at Wanowrie, Poona, has a capacity of 50,000 gallons. The height to water level is 65 ft., the depth of water 10 ft., and the internal diameter 32 ft. *Fig.* 1 is a photograph of this tower taken in April last on the day that it was filled with water and put into use. Scaffolding is still in place, as the approach ladder, top cornice, and other details had still to be put on. The floor slab is 16 in. thick and heavily reinforced. A 3 : 2 : 1 concrete mix of crushed stone, good river sand, and cement of Indian manufacture, was used. There are eight 16-in. diameter exterior round columns battered 1 in 12, and two 18-in. diameter interior round columns. There are two sets of bracings reinforced so as to act both as struts and ties.

In the photograph the crookedness of scaffold poles and props as commonly used in India, tied with country coir string, is well shown, and would appear exceedingly crazy to those accustomed to the straight poles and chain ties as generally used in England. It is, however, curious and fortunate that very few scaffolding accidents occur in India. This water tower was designed and built by Messrs. J. C. Gammon, Ltd., of Bombay,

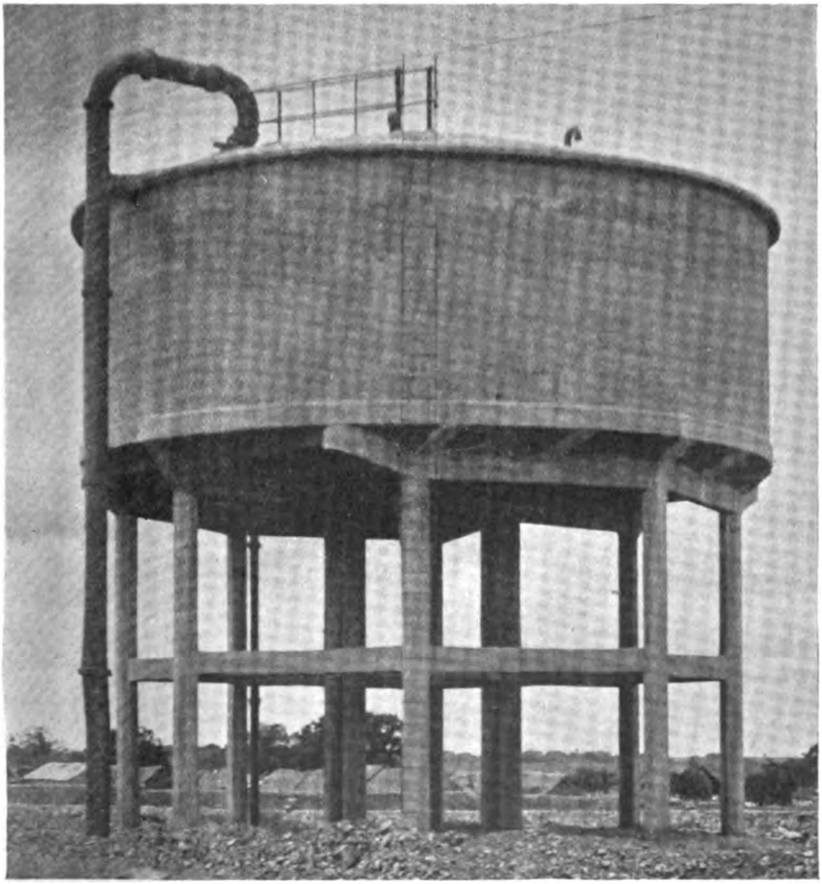


Fig. 2.

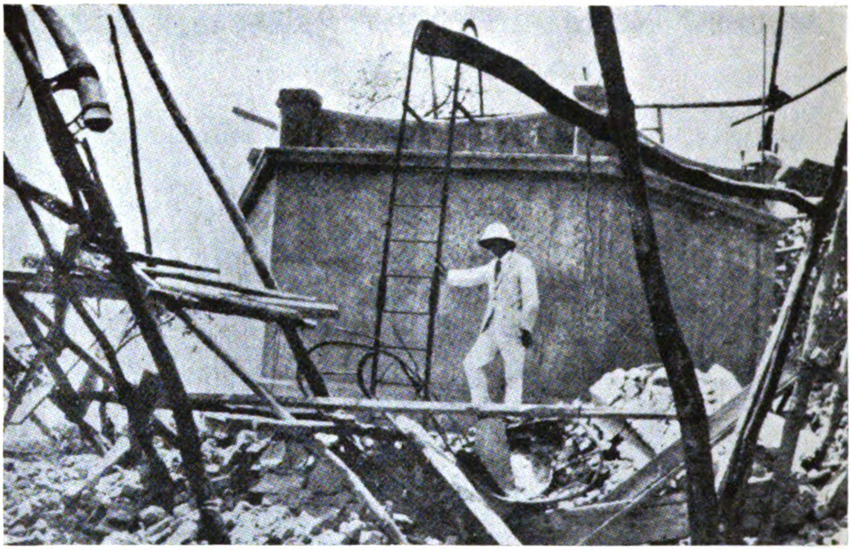


Fig. 4.

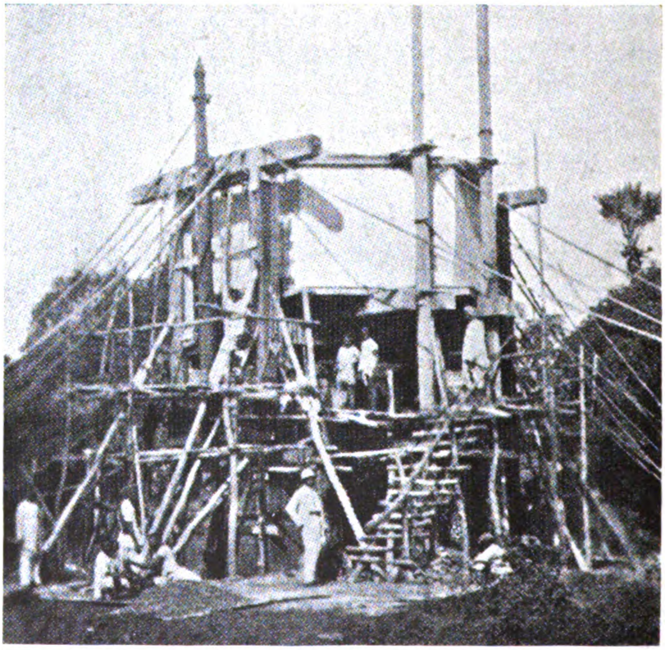


Fig. 5.

Reinforced Concrete Water Towers in India.

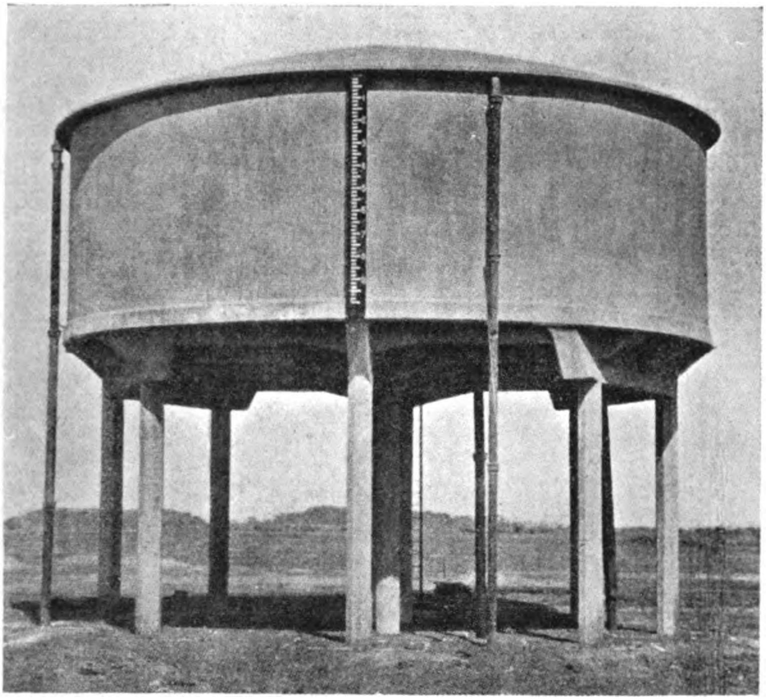


Fig. 3.

for whom the writer is chief engineer, to the general specification and order of Mr. A. P. Maddocks, M.Inst.C.E., Sanitary Engineer to the Government, and Mr. R. A. Collett, A.M.Inst.C.E., Executive Engineer, P.W.D. Poona Water Works.

The order for the work was given on December 8, 1925. The foundations were at once excavated to a depth of about 10 ft. below ground and brought up to 3 ft. below ground level; this excavation in hard moorum and rock was slow and difficult, so that it was only by January 2, 1926, that the reinforced concrete work could be started; yet, as shown in *Fig.* 1, the finished tank, cured of the usual initial sweating, was brought into use on April 1, i.e., in three months. Considering both its great height and size this is considered a remarkable achievement.

Fig. 2 shows a water tower put up ten years ago at Sholapur for the P.W.D. The height to water level is 32 ft., capacity 75,000 gallons, diameter 35 ft. 9 in., and depth of water 12 ft.

Fig. 3 shows a very similar water tower erected about eight years ago at Meerut. Height to water level is 25 ft., capacity 50,000 gallons, diameter 32 ft., and depth of water 10 ft.

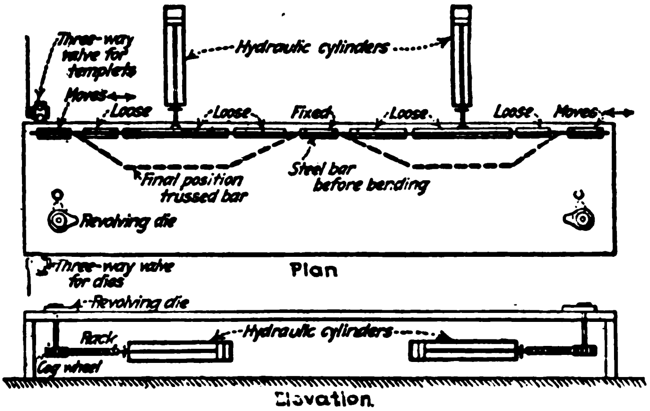
Fig. 4 is a view of a small water tower built several years ago on the top of a brick base 23 ft. high. When half full of water (capacity 10,000 gallons) the brick base gave way, and the fallen tank is here shown with its buckled ladder and brick debris. The tank still held its water, which would have weighed fully twenty tons, and was undamaged beyond a few knocks to its cornice. *Fig.* 5 shows the same tank being jacked up while a new brick base is being constructed underneath. This tank has now been in service for several years.

Hydraulic Bar-Bending Machine.

In building the Flatbush relief outfall sewer in Brooklyn, N.Y., a $3,250,000 project, consisting of something over three miles of reinforced concrete sewer, manual methods for bending the reinforcing steel were found to be very inefficient and costly. The outgrowth of the condition was that the contractor designed and built a machine in which hydraulic cylinder mechanisms bend the reinforcing bars to the proper shapes. Thus, all bending is done at a central bending plant and the steel is transported by truck to the construction operations.

The machine, as described in "Engineering News-Record," consists of a table equipped with a system of guide templets and on each end a set of revolving dies. Some of the templets are fixed and some are loose. The latter are moved by hydraulic pistons, thus bending the steel to the required shape. All steel is bent into either double or single truss bars with hooked ends. The latter are formed by the revolving dies. The first operation consists in placing the truss in the bar by means of the cylinder piston rods. The cylinders are hoist cylinders taken from old motor trucks. The two cylinders move together and are operated by a three-way valve. This three-way valve permits pressure to be put on either side of the piston, thus moving it either forward or backward. The guide templets at each end are fastened to a sliding plate which can move in either direction, thus taking care of the shortening of the bar resulting when it is trussed.

After the truss is placed in the machine the ends of the bar are fastened in the revolving dies. These also operate together, the hydraulic pressure being controlled by means of another three-way valve directly across the table from the one operating the guide templet pistons. As shown in the sketch, the revolving dies are operated by a separate pair of hydraulic pistons placed longitudinally beneath the table. A large gear wheel is mounted horizontally on the vertical shaft of the revolving die. This gear engages a rack attached to the hydraulic cylinder piston.



Hydraulic Bar-Bending Machine.

Pressure is supplied by a triplex pump getting its water supply from a temporary steel tank. A relief valve is placed in the high pressure line of the pump and set at 120 lbs., which is the maximum pressure used on the machine. Oil is placed in the water to lubricate the cylinder parts. As much as 25 tons of double truss steel has been bent and hooked in 8 hours with this machine.

The Simple Theory of Bending.

We have received the following notes on the article by Mr. F. E. Relton, B.A., B.Sc., of the Building Research Station, in our issue for April last :—

In consideration of the fact that the modulus of elasticity of various building materials, above all of concrete, stone, cast-iron, etc., varies for tension and compression, Mr. F. E. Relton has set up an analytical method of calculating the distance of the neutral axis and the stresses in such materials which do not follow Hook's law. The author develops his method, as he says, in the first place quite in general for any form of section to be investigated and then applies it particularly to a section with horizontal axis of symmetry.

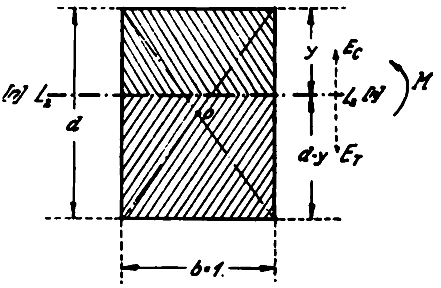
The general case as well as the particular one may, however, only be taken as "general" in a restricted sense. If any moment acts on a section of any form, we require to know not only the distance from the neutral axis to the parallel axis of gravity of the section area, but also the direction of the neutral axis. If the moment acts, for instance, in a vertical plane of forces, it does not follow at all that the direction of the neutral axis is a horizontal one. This is only the case when in the section under consideration the horizontal is a conjugate axis of the vertical, as in principle the line of force and the neutral axis must co-ordinate. In the bending theory for materials with constant modulus of elasticity one can readily determine the direction of the neutral axis for any section either analytically or by the aid of Mohr's circle or of the central ellipse of any three moments of inertia. If, however, there are various degrees, of elongation for tension and compression we must consider the moments of inertia of $E.x$, or simpler $n.x$, the partial areas (e.g. for the compression area $n_C = \dfrac{E_C}{E_C} = 1$ and for the tension area $n_t = \dfrac{E_T}{E_C}$).

As these moments cannot be determined at the outset, however, because they are dependent on the direction and position of the neutral axis, which is to be found, the method is not generally applicable to this purpose. The case dealt with by Mr. Relton can therefore only be considered as a special case, i.e. the case in which the moment acts in a plane of symmetry of the section, for direction of symmetry and plane of symmetry are co-ordinate.

Now for this special case—which is the one most frequently met with in practice—he develops his method of analytically calculating the deviation of the neutral axis from the parallel axis of gravity of the section, and, further, the stresses and the radius of curvature.

The application of this method to even the simplest problem, however, viz. the bending stress in a rectangular section, leads to operations which are not at all simple, and it has the disadvantage that the designer must be familiar with formulæ which Mr. Relton has himself deduced. These simplest problems could probably be quite as easily solved merely by the knowledge that the neutral axis must be the axis of gravity of $n.x.$ the partial areas. The rest could then readily be found, taking into consideration the n^{th} values in general.

The rectangular section under consideration would result as follows :—



$$n_C = 1$$

$$n_T = \frac{E_T}{E_C} = n$$

$$\frac{by^2}{2} = n\frac{b(d-y)^2}{2}$$

$$y^2 = n.d^2 - 2n.d.y + n.y^2$$

$$y^2(1-n) + 2n.d.y - nd^2 = 0$$

$$y = \frac{-2n.d \pm \sqrt{4n^2.d^2 + 4(1-n).n.d^2}}{2(1-n)}$$

$$y = d\frac{\sqrt{n} - n}{1 - n}$$

For the corresponding values :—

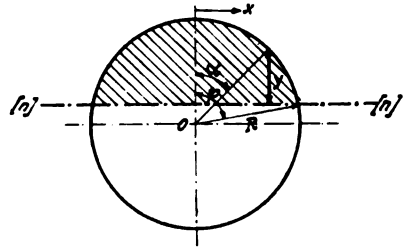
$$E_c = 11,\ E_T = 10 : n = \frac{10}{11}$$

we get $y = d\ (\sqrt{110} - 10) = 0{\cdot}488d$, that is to say, the deviation K from the axis of gravity would also be—

$$K = 0{\cdot}500\,d - 0{\cdot}488\,d = 0{\cdot}012\,d \sim \frac{1}{80}d$$

$$K = \sim \frac{1}{80}.d$$

In circle and annular sections the solution of the problem becomes quite complicated, even by Mr. Relton's method, although the integrals for the static moments of the segments may be solved and the resulting transcendant equation may be evaluated. For instance, in the case of the circle the static moment of the segment would result as follows :—



$$S_n = 2\int_0^{R\sin\varphi}\frac{y^2}{2}.dx = R^3\int_0^{\varphi}(\cos\alpha - \cos\varphi)^2 \cos\alpha d\alpha$$

$$= R^3\left[\frac{\sin\varphi}{3}(2 + \cos^2\varphi) - \varphi.\cos\varphi\right]$$

The tediousness of solving this integral in general—which Mr. Relton proposes to avoid by means of his method—goes to support the opinion that it would appear to be preferable to employ graphic methods for such problems rather than attempt analytical solutions. The graphic method used directly to determine the neutral axis leads to the most simple solution conceivable for all forms of section in which the direction of the neutral axis is known, without the degree of accuracy falling below the limit permissible in practice. In this method the section is divided into partial areas, a parallel of the known direction of the neutral axis takes the n^{th} partial areas as forces, which act in a parallel direction in their respective centres of gravity and describes for them two polygons of forces of equal polar distance in accordance with the two values of n. Then we draw the two corresponding link polygons starting, for instance, from a straight line parallel to the plane of moments (line of force). The required neutral axis then passes through the point of intersection of these two link polygons. The moment of inertia of the n^{th} partial areas in reference to this neutral axis is (according to Mohr)

$$T = 2H.P^1$$

in which H is the polar distance of the polygons of forces and P^1 the area enclosed by the link polygons and the initial straight line (1st polar line). The rest, such as stresses and radius of curvature, is obtainable in the simplest manner after this preliminary graphic calculation. It is superfluous to go into further details, as the method may be presumed to be well known.

Now, if the use of this graphic problem is an advantage it may be utilised in a considerably wider field without involving any considerably greater knowledge of the subject. For instance, it may not only be used for problems in which the material has varying moduli for tension and compression, but in general where the various parts of a section are subject to different degrees of elongation. For this reason it has been most extensively used, for example, in reinforced concrete. Subject to a little development it may also be used to solve the difficult problem of calculating stresses where we have finite distance of the acting force, that is, when bending and axial forces act together. Further, this method presents the most serviceable means for determining the neutral axis and the stresses in the general case where any moment acts with or without axial force on an unsymmetric section (that is, any section), as an assumed direction of the neutral axis may be verified as to its accuracy.

However good Mr. Relton's analytical method may be, I am still of the opinion that in practice the graphic method will keep its ground as being the more efficient.—N. K.

Compression Tests of Concrete.

As the result of tests on some 3,000 cylinders made of four different concrete mixes to determine the influence of uneven end surfaces, and of different methods of capping, on the reliability of compression tests of 6 in. by 12 in. concrete cylinders, Mr. H. F. Gonnerman, of the Structural Materials Research Laboratory, Lewis Institute, Chicago, gives the following conclusions :—

(1) The standard method of moulding and capping concrete cylinders with machined base and cover plates gave uniformly high strength equal to or greater than that from any of the other methods.

(2) Deflection of the table of the testing machine used was small, and had practically no effect on the test results.

(3) For reliable results the use of the adjustable block with spherical bearing surfaces was found to be essential. A spherical bearing block with hardened steel balls between the spherical surfaces gave essentially the same results as the plain spherical block.

(4) No difference in results was found when spherical bearing blocks were used in the following positions : (*a*) on top of cylinder ; (*b*) inverted on top of cylinder ; (*c*) beneath the cylinder ; (*d*) both on top and beneath the cylinder.

(5) Small errors (¼ in. or less) in centering the bearing block on the cylinder had little or no effect on the test results. An error of ½ in. in setting gave strength-ratios of about 90 per cent. for 1 : 5 and 1 : 3½ concrete.

(6) Cylinders moulded on a plane cast-iron base and with top trowelled smooth showed the following results when tested as indicated :

(*a*) With thin caps of gypsum or mixtures of cement and gypsum, the results were essentially the same as those obtained for the standard method of capping.

(*b*) Without bedding, the strength-ratios obtained were about 95 per cent. for 1 : 7 concrete, 94 per cent. for 1 : 5 concrete, and 80 per cent. for 1 : 3½ concrete.

(*c*) With sheet materials between top of cylinder and the spherical block, the strength-ratios obtained were less than 100 per cent. for all of the materials used.

(*d*) For the sheet materials, the best results were obtained with Beaver board, which gave strength-ratios of about 100 per cent. for 1 : 7 and 1 : 5 concrete and about 90 per cent. for 1 : 3½ concrete.

(*e*) For white-pine board, mill board, and leather the strength-ratios ranged between those found for Beaver board and those found for no bedding (see (*b*) above).

(*f*) For the other sheet materials, blotting paper, sheet lead and rubber the strength-ratios were less than those found for no bedding.

(*g*) The lowest strength-ratios were found for the $\frac{1}{16}$-in. sheet rubber ; they were about 80 per cent. for 1 : 7, 70 per cent. for 1 : 5, and 50 per cent. for 1 : 3½ concrete.

(7) Cylinders made and capped by the standard method, tested with a ½-in. segment (circular segment of ½-in. mid-ordinate) of the cap removed, gave strength-ratios slightly less than 100 per cent. When a 1-in. segment was removed the strength-ratios obtained were 100 per cent. for 1 : 7 concrete, about 95 per cent. for 1 : 5 concrete, and 90 per cent. for 1 : 3½ concrete. The removal of a 2-in. segment gave strength-ratios of 90, 80, and 65 per cent. for the three grades of concrete. When the segments removed were replaced with 1 : 1 gypsum and cement mortar 3 hours before test, the strength-ratios were about 100 per cent. except for the 2-in. segment, which showed strength-ratios of from 95 to 90 per cent.

(8) Cylinders with plane parallel ends but with axes inclined gave the same strength as standard cylinders for an inclination of ¼ in. in 12 in. and strength-ratios of about 92 per cent. for an inclination of ½ in. in 12 in.

(9) Cylinders with the top surface inclined showed strength-ratios of about 100 per cent. for an inclination of ¼ in. in 6 in., and about 95 per cent. for an inclination of ½ in. in 6 in.

(10) Cylinders moulded with machined cast-iron plates so as to give convex ends, and tested without bedding, gave pronounced reductions in strength even for a small amount of convexity. The reduction in strength increased with increase in convexity and with increase in the richness of the mix. For a convexity of 0·01 in. the 1 : 3½ and 1 : 2 mixes showed strength-ratios of about 65 per

cent.; and for a convexity of 0·05 in., about 40 per cent. For the 1 : 7 and 1 : 5 mixes the corresponding strength-ratios were about 80 and 55 per cent. When tested with Beaver board sheets at both top and bottom the reductions in strength were about half as great as when tested without bedding. The use of gypsum bedding for one group of cylinders with bases convex 0·05 in. gave strength-ratios of about 90 per cent.

(11) The effect of concave ends was small compared with that of convex ends.

(12) Sheared steel plates 8 in. square by ½ in. thick, from warehouse stock, showed deviations from a true plane of as much as 0·012 in. Cylinders moulded with these plates as bases and covers so as to give convex ends gave results comparable with those from cylinders having the same convexity similarly made with machined cast-iron plates (see 10).

(13) Tests with concrete of different consistencies using cylinders with ends convex about 0·01 in. showed similar results for all consistencies. The typical relation of strength to water-cement ratio was found.

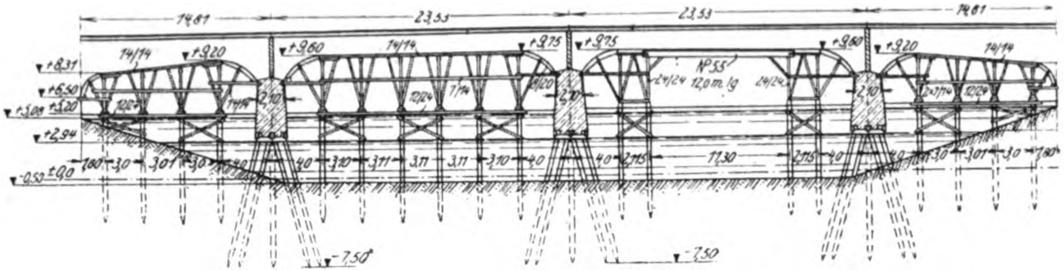
(14) The different conditions of test did not show a marked difference in the uniformity of the individual results. The average mean variation ranged from 4·1 per cent. for one group of the standards to a maximum of 10·9 per cent. for the cylinders tested without an adjustable bearing block.

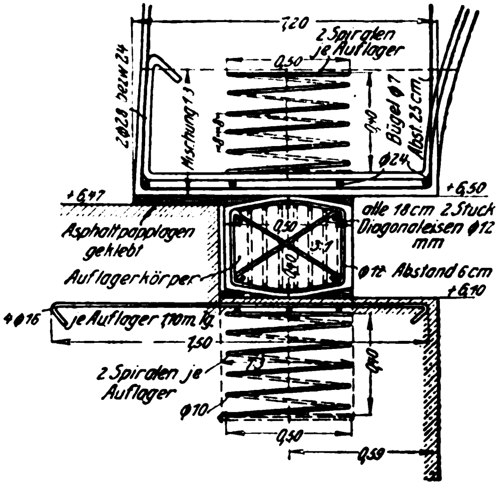
(15) Finally, the most important conclusion from these tests is that great care must be exercised when preparing cylinders for test in order to secure ends which are true planes. When the standard method of capping with plane cover plates cannot be followed, the cylinder should be trowelled smooth and bedded with a thin layer of gypsum or a mixture of gypsum and cement 3 to 6 hours before test. The cylinders should always be moulded on a plane surface.

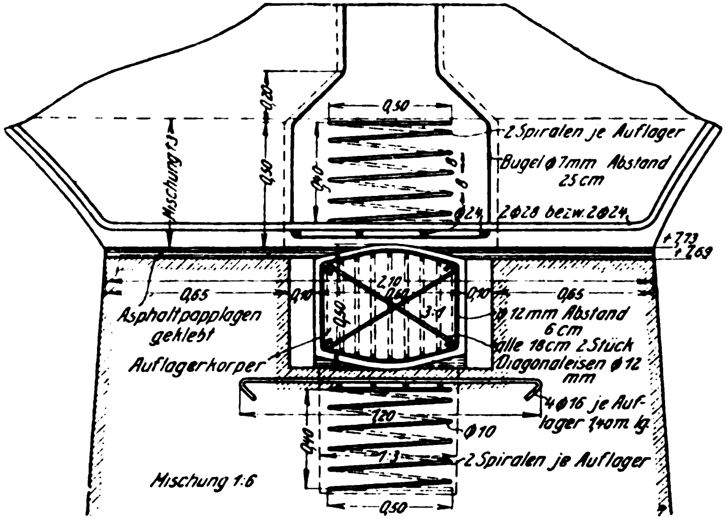
Bridge over Tidal Canal at Hamburg.

An improvement scheme on the banks of the Elbe has rendered necessary the construction of a series of bridges, the most interesting of which is described in a recent issue of "Beton u. Eisen."

This bridge, over the tidal canal, consists of four continuous spans supported on piers founded on timber piles. The lengths of the two interior spans are 77 ft. and of the two end spans 50 ft. 6 in., and a minimum clearance over mean high-water mark of 31 ft. 7 in. by 12 ft. 9 in. is maintained under the pair of central spans. Owing to the length of the spans particular care had to be exercised to deal with possible expansion and contraction. The method of dealing with this part of the design is perhaps the most interesting feature of the bridge. The central support of the five is taken as fixed, and movement of the spans allowed over the outer piers and the abutments. These latter, of which the details are given in the illustrations, are designed as spiralled compression members for a stress intensity of 1,000 lbs. per sq. in. Layers of asphalted paper separate the reinforced concrete superstructure from the mass concrete piers. These piers are supported on piles of Scots pine with a mean diameter of 14 in. and a load of 35 tons on each. The factor of safety is three. A timber cut-water encloses each timber pier.—W. S. G.





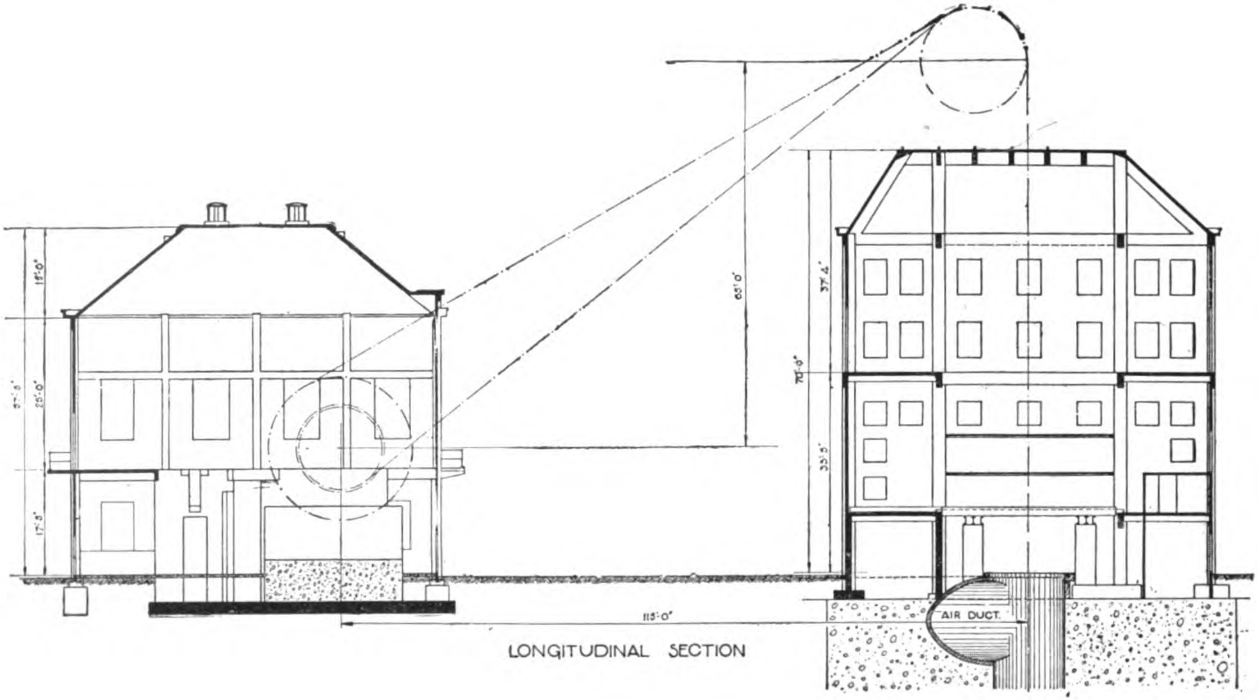


Top: General Arrangement of Centering.

Left: Detail of Bearing at Abutment.

Right: Detail of Bearing at Side Pier

Bridge over Tidal Canal at Hamburg. (*See p.* 436.)



Winding Engine House at Denaby Main Colliery. (*See p.* 439.)

Modern Practice in Reinforced Concrete.

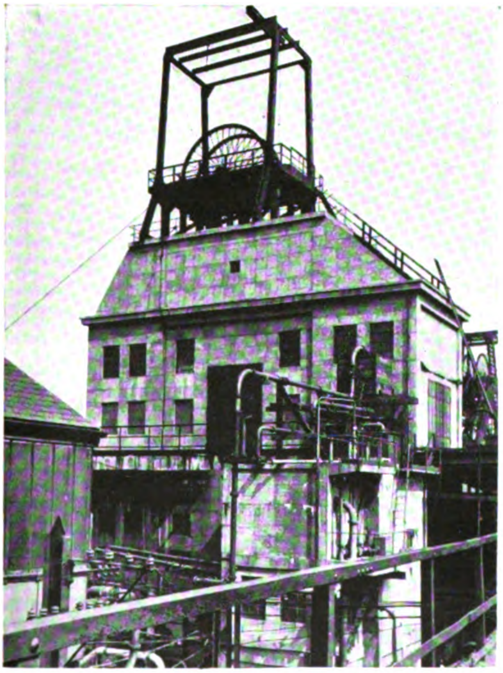
By G. P. MANNING, M.Eng., A.M.Inst.C.E.

At a recent meeting of the Association of Mining Electrical Engineers, held at Newport, Mon., Mr. G. P. Manning, M.Eng., A.M.Inst.C.E., read a paper in which he gave his views on modern practice in reinforced concrete, with particular reference to mining structures.

Reinforced concrete structures, he said, were now sufficiently numerous to enable some sort of verdict to be pronounced as to their usefulness. They found structures built to carry heavy loads and subjected to most severe test-loads. In most cases the deflections were very small and were mostly elastic: that was to say, that when the loading was removed the structure returned to its original shape and line. There seemed to be no grounds for doubting the strength of reinforced concrete work, provided that the designing engineer was reasonably competent and the contractor sufficiently experienced in this class of work.

The only way to make a reinforced concrete structure resist deterioration was to employ nothing but a very high grade of concrete. Reinforced concrete was still suffering from the methods of making concrete which were employed in former years on mass-concrete work. When constructing massive blocks of concrete a mixture proportioned 1 : 2 : 4 was sufficiently rich to produce a hard concrete even if the sand and ballast were badly graded or not over-clean. A slight roughness or pitting of the surface in a large block after 20 years' service was of little or no account. In many cases in reinforced concrete work the smaller bars were placed only half-an-inch from the exposed surface, and in this case weathering of the surface was a very serious matter. The question immediately arose: How could a strong and lasting mixture of concrete be ensured?

First of all, by careful attention to the



Winding Engine House at Denaby Main Colliery.

choice of sand and ballast. Cleanliness of the materials was essential. No materials should be employed unless they had been washed free from all earth and clay. Careful attention to the size of the particles which composed the sand and the ballast would result in a stronger and denser concrete. The question of grading sands and coarse aggregates and proportioning concrete had been developed to an amazing degree, especially in American literature. In practical cases, however, there was a distinct limit to which one could go in choosing and grading aggregates.

Another point which required attention was the amount of water employed in mixing. The concrete should be as dry as possible, consistent with easy placing and ramming round the reinforcing bars.

If all precautions were taken they certainly could produce a strong and dense concrete from a 1 : 2 : 4 mixture. But the process allowed little or no margin of error. At the present day it was usual to use a richer mixture for water-tight work and there was already a tendency to advocate a richer mixture of, say, 1 : 1½ : 3 for all structures. It was probable that in a few more years, when reinforced concrete structures had had more time to demonstrate their ability to resist the action of the weather, a richer mixture would be universally adopted in this country. This should eliminate failures due to poor concrete and enable engineers to work to higher stresses and design lighter structures accordingly.

An urgent need was for the more general adoption of some reliable method of keeping the bars in place during concreting and thus making sure that they were properly protected by the concrete. The precautions taken by some contractors in this respect could only be described as primitive. In consequence it sometimes happened that the bars moved about during concreting, and when the shuttering was struck the bars were actually exposed to view and had to be plastered over. It was sincerely to be hoped that the future would see a general improvement in this respect.

At the conclusion of the lecture the author showed a number of lantern slides of colliery buildings at home and abroad, including the winding engine house at Denaby Main Colliery (illustrated herewith—*Figs.* 1 and 2), carried out by Messrs. Peter Lind & Co.

A New Concrete Journal.

We have frequently been asked to supply a journal specially devoted to concrete products and the smaller type of concrete building, and we feel that with the extraordinary growth of the industry the time has now arrived when we are justified in complying with this generally expressed wish. We have therefore decided to publish a new monthly periodical, with the title "Concrete for the Builder and Concrete Products," the first number of which will be ready on July 1. This journal will be essentially a journal for the builder and products manufacturer, and will present informative and valuable articles on all aspects of the use of concrete in a readily understandable manner.

The products manufacturer whose business is already highly efficient cannot fail to gain by knowing what other efficiently-run businesses, both at home and abroad, are doing. The architect or builder interested in the use of pre-cast concrete or the erection of small concrete buildings will be able to see the latest methods of carrying out his work. The builder who has not attempted to make concrete goods will be shown that it is often a paying proposition. Science and theory, in so far as they are helpful to the manufacturer of concrete products and the concrete builder, will be presented in simple language.

We have arranged with many specialists to act as contributors, and we have also made arrangements for our subscribers' problems to be solved free of charge by experts in all branches of concrete construction and the manufacture of concrete products.

The price has been fixed at the low figure of 4*d*. a copy. A specimen copy will be sent to any of our readers who apply for one, or the journal may be ordered by filling in the subscription form on page xxxvi.

Concrete Cribbing for Railway Retaining Walls.

INCREASING use by several railways of retaining walls of concrete cribbing, built up of pre-cast concrete members, indicates some substantial advantages over monolithic concrete walls of either gravity or reinforced types, says "Engineering News-Record." Low first cost, simplicity of foundation work, rapidity and convenience of construction, facility for removal or alteration where eventual reconstruction is foreseen, and high salvage value in case of removal, are among the advantages noted by different railroads. In four designs now in use, two form an open face or wall, while the other two form a closed or solid wall. Three of them are built of interlocking members, while in the fourth the members are pinned together with loose iron rods or drift bolts set in cored holes and then grouted.

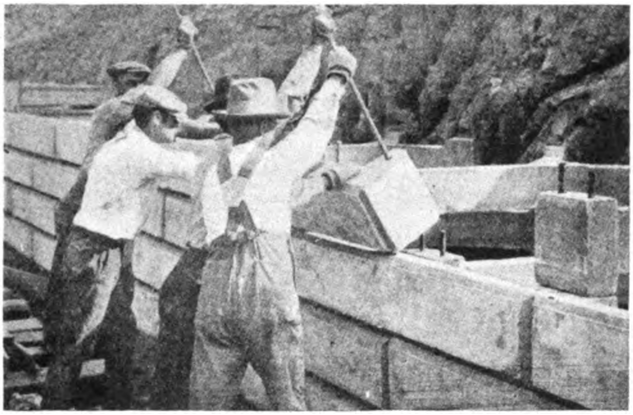


Fig. 1.—Solid-Face Crib Wall.

A new type of concrete cribbing which has the special feature of giving a solid face or wall, instead of the usual open crib-work construction, has been used on the extensive track depression of the Grand Trunk Railway along its De-Quindre Line at Detroit, Mich. On this work a four-track roadbed is spanned by numerous street bridges. In the spaces between the bridges, concrete crib walls about 6 ft. high, built in line with the faces of the abutments, retain turfed slopes extending to the right-of-way lines at the street surface. The slope begins a little back from the face of the wall and is rounded off from the top of the wall; this arrangement is designed to hold the sodded slope from slipping due to the soft clay soil. The cribbing is filled with cinders and sand. One of these walls under construction is shown in *Fig.* 1, while *Fig.* 2 shows the details of the members.

Stretchers 6 ft. long, forming the entire face of the wall, are of channel shape in plan, with holes in the end lugs or flanges to engage steel dowels embedded in the ends of header members or anchors of Y-shape which are embedded in the fill. With this construction, the headers do not extend through the wall to its face, while their Y-shaped ends form effective anchors to hold the wall in straight line and surface. As the stretchers are laid to break joint, the headers also are staggered, so that the ends of each Y in one course rest upon the ends of two Ys in the course below. This arrangement is indicated by the plan of alternate courses in *Fig.* 3. No dowels are used in these rear connections.

A departure from ordinary masonry construction is that the stretchers are not in contact for their full length, but have end bearings 7 in. long (see *Fig.* 2), the bottom being cut away between these bearings so as to leave a 1-in. space or slot. With this arrangement a definite bearing at the joints is ensured in case of irregular settlement of the wall. These slots, which serve to provide for drainage of the fill, are not noticeable in the completed wall, being concealed by the chamfered edges of the faces of the blocks.

The stretchers, 6 ft. long and 4½ in. thick, with an effective depth of 12 in., weigh about 320 lbs. and contain 2¼ cu. ft. of concrete and 18 lbs. of steel. The headers in this installation are 5 ft. 8 in. long, but for higher walls their length is 8 ft. They have a uniform spread of 3 ft., and weigh 360 and 430 lbs. respectively; in the longer stretchers, the quantities are 3 cu. ft. of concrete and 27½ lbs. of steel, while the shorter ones have 2½ cu. ft. and 23 lbs. respectively. Short stretchers, having a lug at one end only and a dowel hole in the other end provide for filling out at corners or at angles in the face of the wall (see *Fig.* 3).

In the railway company's specifications a 1 : 2 : 4 concrete mix is required, using either crushed stone or washed and screened gravel for the coarse aggregate, with the minimum amount of water necessary to produce a plastic or workable mixture. A smooth float finish is given to the face of the stretchers. The holes and dowels are spaced accurately in the forms by means of templets. Reinforcing steel consists of deformed bars, but the dowels are plain round bars. To protect the exposed parts of the latter from rust, these parts are dipped in a bituminous composition before the rods are set in the

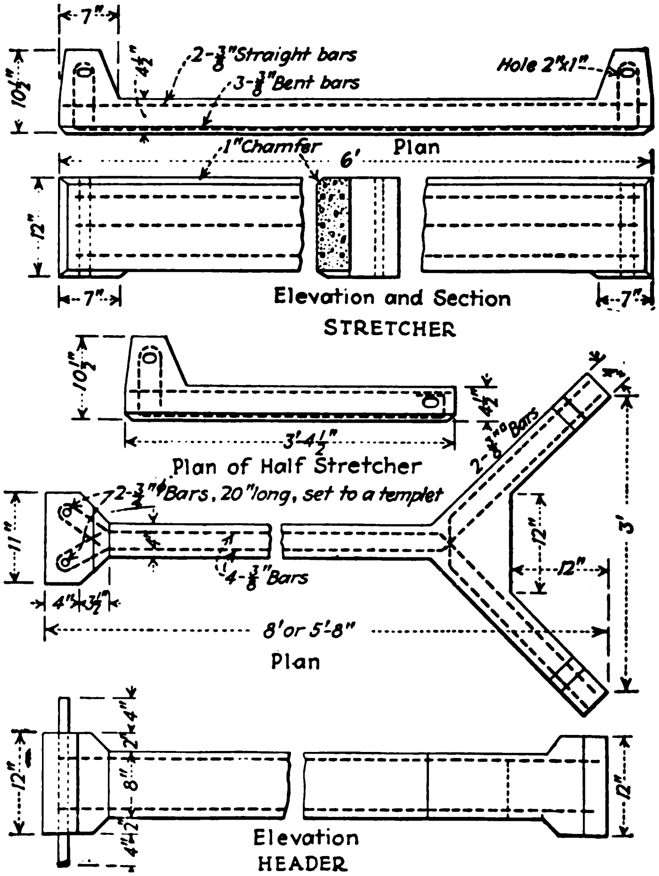


Fig. 2. - Members for Solid-Face Cribbing.

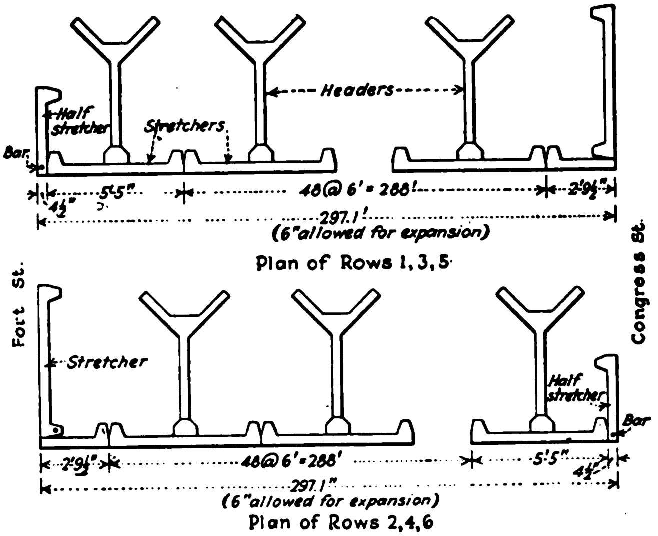


Fig. 3.—Alternate Courses of Cribbing.

forms. The pre-cast members were delivered in box cars, unloaded by hand and set in place by hand, without the use of a derrick.

This concrete cribbing construction is reported as being cheaper than poured concrete retaining walls of gravity or reinforced section. This work is all under the direction of Mr. J. A. Heaman, chief engineer, Grand Trunk Railway, and Mr. F. P. Sisson, division engineer in charge of construction.

For the retaining wall of a Chicago track-elevation fill along property lines, where the wall need not be built to full height at present, the Illinois Central R.R. is using concrete cribbing, as estimates showed that it would be far cheaper

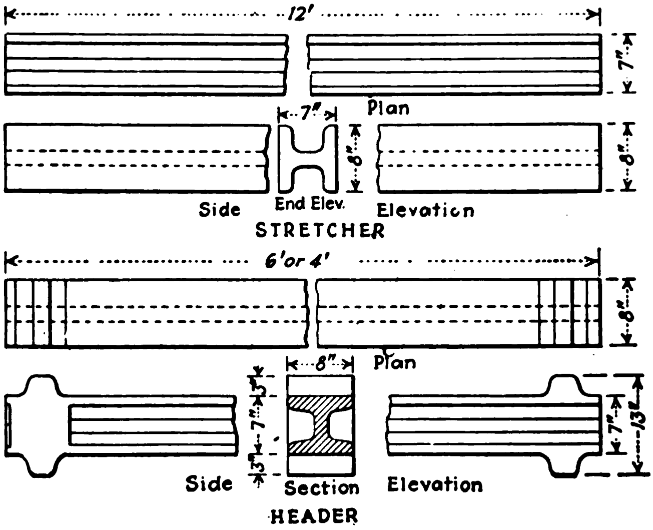


Fig. 4.—Members for Open-Face Cribbing.

to adopt this method than to build a solid retaining wall of full height. Eventually such a wall may replace the cribbing, the latter being then removed. Economy in construction cost, complete interlocking of the cribbing, and large amount of salvage were leading factors in the selection of this type of wall.

This crib wall is built of interlocking members of I-beam section. As shown in *Fig.* 4, the headers or transverse members have T-shape heads to fit into the longitudinal members or stretchers, which are laid flat. In general, the interlocking is relied upon to hold the members in place, but in order to ensure firm bearings it was necessary in some cases to chip away the concrete or to use cement grout. No footing is built, the base of the cribwork being laid in a shallow trench in the surface soil. This cribbing, which is being used for a length of about 1955 ft., has a maximum height of about 10 ft. with a face batter of 2 in. per foot. It has a width of 4 ft. for the two lower and two upper tiers, and 6 ft. for the remainder. The cribbing is sufficiently close to prevent much of the fill from material-spilling through the openings in the face. In construction, the cribbing was erected by hand at the rate of about 480 sq. ft. of wall per day; filling was deposited at the same time so as to anchor the lower part in position while the upper courses were being placed.

A type of interlocking concrete cribbing which was developed on the Chicago, Rock Island & Pacific Railway, consists of stretchers having mortised ends forming recesses to receive the flat T-heads of the headers. The stem of the header passes between the two stretchers, so that both stretchers and headers form the face of the wall. This crib wall construction has been used on track elevation work at Chicago and other cities. In the three types of cribbing above described, which are all patented, two have interlocking members, and one has the members put together with dowels which are cast in the concrete, so that this design also may be termed interlocking.

A simple and unpatented type of cribbing which has been developed on the Chicago & North-Western Railway consists of concrete beams 6½ ft. long, of rectangular section, 8 in. by 8 in., each having three cored holes. Iron rods or drift bolts are set in these holes, which are grouted as the beams are built up or threaded on the rods. This construction forms a solid instead of an open face, but differs from the solid-face cribbing on the Grand Trunk Railway in that the headers extend to the face of the wall, alternating with the stretchers.

New Reinforced Concrete Bridge in France.

On p. 445 we illustrate a reinforced concrete bridge which carries the road from Chambery to Belley across the river Rhône, replacing a suspension bridge built in 1837. A competition for designs in reinforced concrete was held, from which the design submitted by the Hennebique Company was selected and carried out.

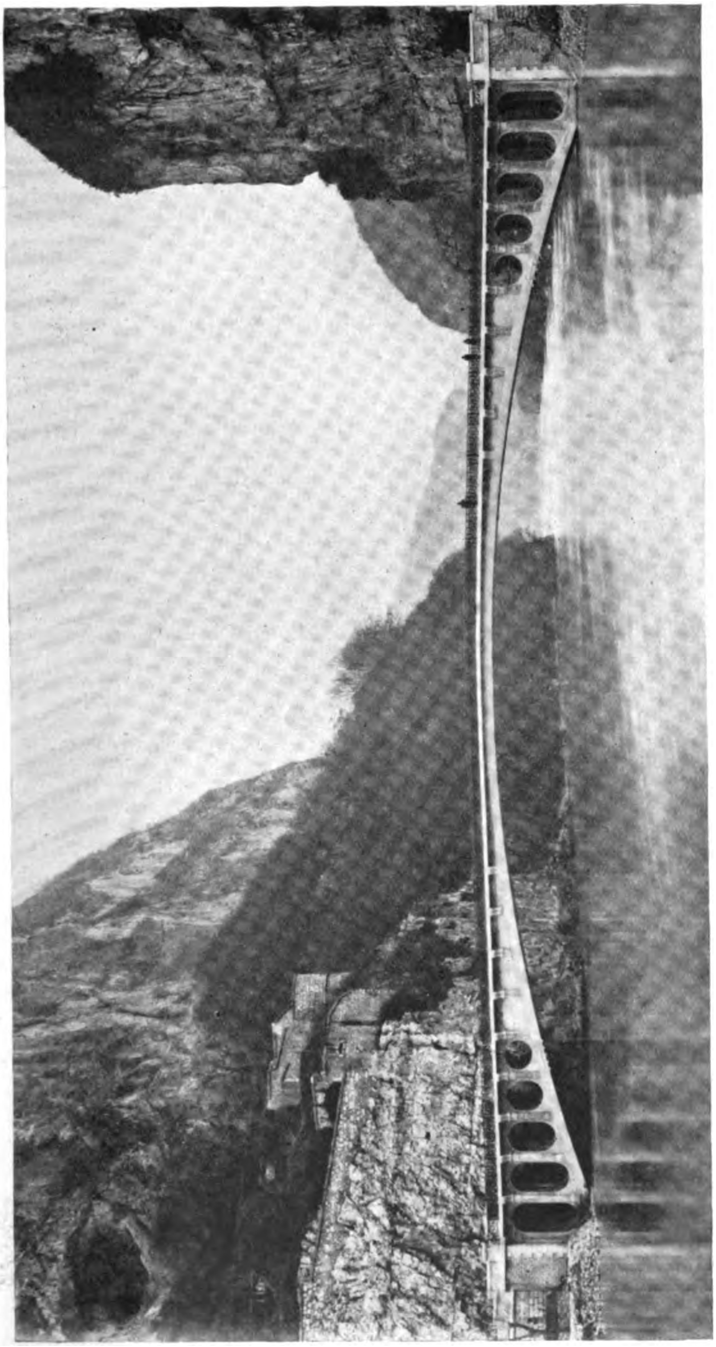
The arch has a span of 311 ft. and a width of 29 ft. 6 in. In the preliminary calculations use was made of a glass model of the type used by Professor Mesnager, in which changes in shape are indicated by tints in the glass when it is illuminated by a polarised light. The design is for both ends fixed and embedded in the abutments at the springing.

The arch has a uniform thickness of 2 ft. 6 in., upon which the carriageway and footpaths are supported by three rows of columns of heights diminishing towards the centre, where the space between the arch and the roadway is filled in with a light concrete wall.

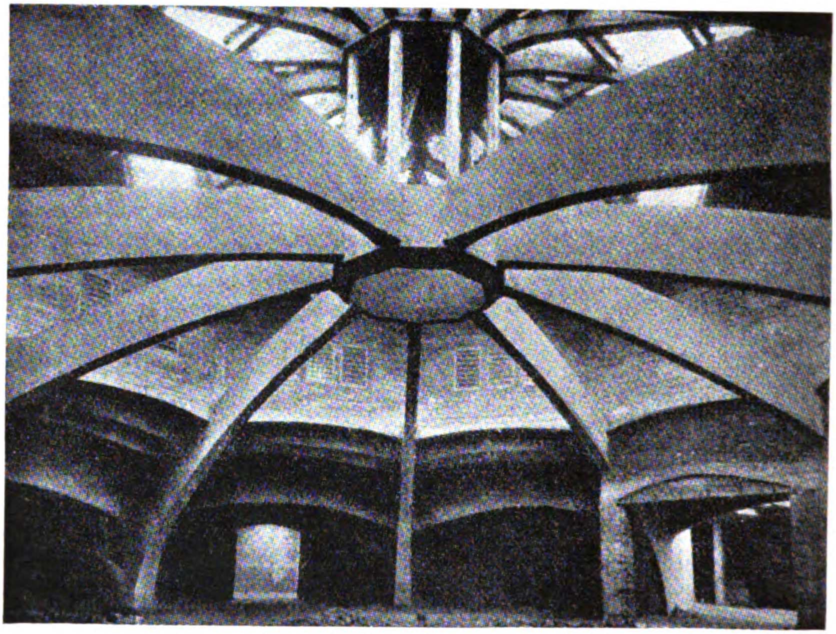
The roadway is 6½ in. thick and the footpaths 3½ in., supported by three main longitudinal beams corresponding with the three rows of columns and four secondary beams in sets of two between the main beams. Transverse beams are placed at 11 ft. centres. The arch was built in two stages, the lower layer of 1 ft. 4 in. being poured first, followed by the top layer of 1 ft. 2 in. The ornamental parts of the bridge are of pre-cast concrete.

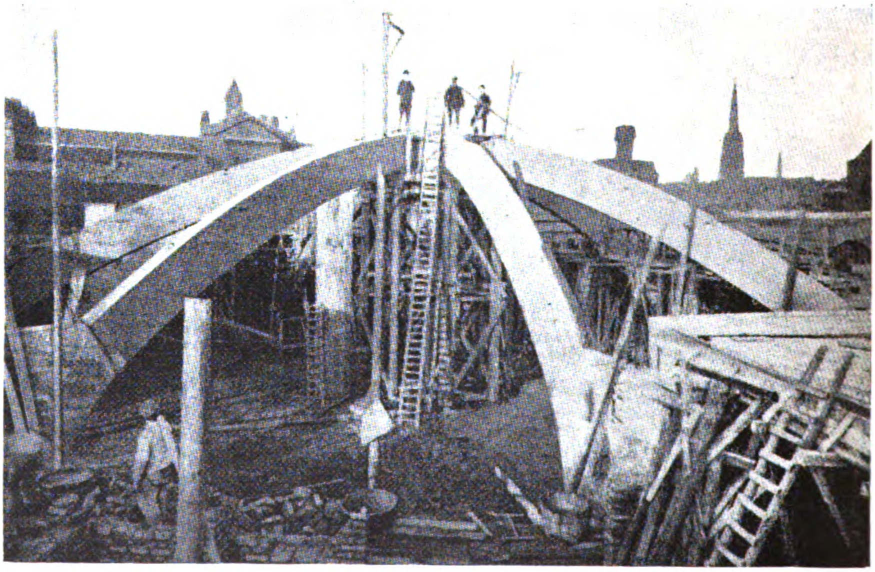
During construction difficulty was experienced in getting a good foundation for the abutments. The abutment on the left bank of the river was secured to the rock by steel bars embedded in the rock and projecting into the concrete, a cofferdam being necessary for the carrying out of the work.

REINFORCED CONCRETE BRIDGE IN FRANCE.



Reinforced Concrete Bridge across the Rhône, France. (*See p.* 444.)





An Unusual Pre-Cast Concrete Dome. (*See p.* 447.)

An Unusual Pre-Cast Dome.

THE remarkable building of which we give some illustrations, reproduced from "Beton u. Eisen," was erected by Wayss & Freytag in Aachen in 1924.

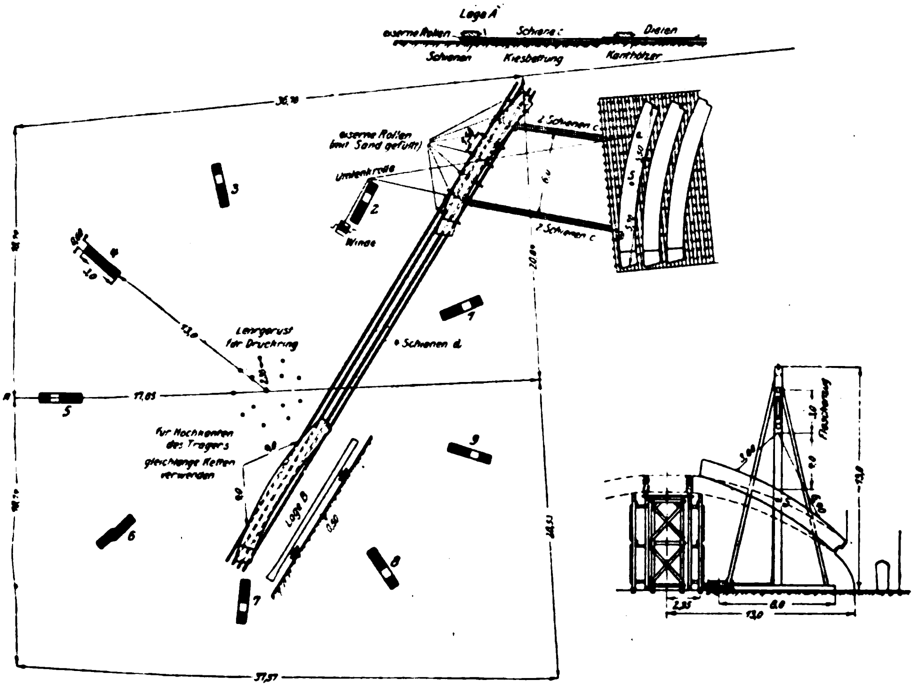
In plan there are nine ribs, giving a span of about 80 ft., which meet on a circular girder at the crown of the arches. Above this point the lantern tower is supported, and against this tower the inner ends of the ribs carrying the glassed roof of the main building bear. As will be seen from the drawings, a series of offices is provided above the main ribs.

Owing to foundation difficulties a hinged structure was alone suitable, and the stresses on the ground were kept low. For the abutment design two cases were considered, (1) Wind load on dome + smallest horizontal thrust due to dome, and (2) No wind and maximum horizontal thrust due to dome.

The horizontal thrusts in a rib under the varying conditions of loading were as follows:

	Tons.
(1) Due to dead weight of curved rib . .	H = 11·70
(2) Due to symmetrical dead loads on rib .	H = 38·12
(3) Due to live load on one side only . .	H = 0·90
(4) Due to wind . .	H = 0·38

The erection was carried out by means of a hoist for handling the ribs, which had been pre-cast and allowed to harden for three weeks. Each of the ribs weighed about 10 tons. In this way expensive shuttering was dispensed with. The lay-out of the erection plant is shown in the accompanying illustrations.—W. S. G.



Erection Lay-out of Pre-Cast Dome.

Design of Reinforced Concrete Members for Bending combined with Thrust or Tension.

By OSCAR FABER, O.B.E., D.Sc., M.Inst.C.E.

MEMBERS subject to bending combined with thrust include arches, many members in trusses, and nearly all pillars, columns, piles, etc., which are, as a rule, more or less eccentrically loaded.

Members subject to bending combined with tension include silo walls and many members in trusses.

This is sufficient evidence that the subject is an important one. In reinforced concrete it is also a difficult one, and in the author's opinion has so far been inadequately treated.

In his *Reinforced Concrete Design*, Volume 1, written with the collaboration of Mr. P. G. Bowie, the subject was treated in Chapter III. Perhaps after ten years it is not surprising that the author has groped his way to a fuller and more helpful treatment.

In his present view, the original treatment suffered from two defects :—

1. That the position of the resultant thrust or tension was assumed to be known. It is in some cases, but not in all. When, for example, the moment M and the direct force P are given (quite a common case), then the eccentricity

$$e = \frac{M}{P} \text{ is determined,}$$

but, until the centroid is calculated, neither $e - f$ nor $e + f$ are known. No method of calculating f was suggested, and yet $e - f$ and $e + f$ were the basis of the treatment given. The importance of this will be grasped when it is mentioned that f may vary from o to d, and may be large compared with e.

2. No ready method of selecting a suitable section in a given case was given, all that was offered being a method of calculating stresses in sections chosen more or less at random. The treatment now offered remedies these defects, and tends, it is hoped, to a clearer understanding of the subject and a much readier solution of problems.

The subject is conveniently separated into bending and tension, and bending and compression.

The article limits itself to the design or analysis of cases when the moment and forces are known, the calculation of these being outside its scope.

The following notation is used :—

a = radius arm, distance from centre of tension to centre of compression.

$a_1 = \frac{a}{d}$

b = breadth.

d = depth, measured to the tensile reinforcement.

n = depth of the neutral axis.

$n_1 = \frac{n}{d}$

$m = \left\{ \begin{matrix} \text{modular} \\ \text{ratio} \end{matrix} \right\} = \frac{\text{elastic modulus of steel}}{\text{elastic modulus of concrete}} = 15$

g = depth of the centroid or centre of gravity. In its calculation, the concrete in tension is ignored, and the steel is replaced by m times its area of concrete.

$g_1 = \frac{g}{d}$

f = distance of centroid from tensile reinforcement.

$f_1 = \frac{f}{d}$

t = tensile stress (generally in tensile reinforcement).

c ⇒ compressive stress (generally in concrete).

t_1 = ratio of stresses $\frac{t}{c}$

r = ratio of steel to concrete $= \frac{A}{bd}$

M = moment.

P = direct thrust or tension.

T = total tension in tensile reinforcement.

C = total compression.

A = area of steel reinforcement.

Forces are in lbs., lengths in inches, stresses in lbs. per square inch.

In the following treatment, the assumptions are made :—

(1) The resistance of concrete to tension is ignored.

(2) The modular ratio is taken as constant and equal to 15.

(3) Plane sections are taken as remaining plane after bending.

Bending and Tension.

Case I: Where Both Sides are in Tension.

This occurs when the resultant P lies inside the limits of d and only members reinforced on both sides are suitable for such loading.

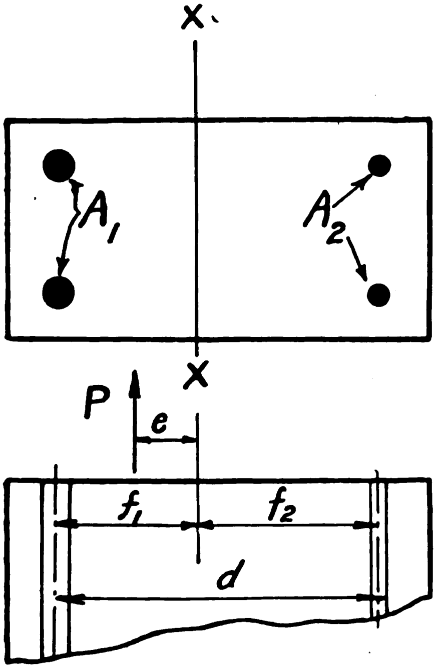


Fig. 1

In the following formulæ, the tension is assumed to be taken up entirely by the steel alone.

Let stress in $A_1 = t_1$

" " " $A_2 = t_2$

The centroid XX is determined by :—

$$f_1 = \frac{A_2 d}{A_1 + A_2} \quad . \quad . \quad . \quad 1$$

$$f_2 = \frac{A_1 d}{A_1 + A_2} \quad . \quad . \quad . \quad 2$$

and if e is the eccentricity about the centroid, then :—

$$t_1 = \frac{P}{A_1}\,\frac{e + f_2}{d} \quad . \quad . \quad . \quad 3$$

$$t_2 = \frac{P}{A_2}\,\frac{f_1 - e}{d} \quad . \quad . \quad . \quad 4$$

Example 1 : $A_1 = 6$ in.²
$A_2 = 3$ in.²
$d = 10$ in.
Moment $M = 100{,}000$ in. lbs.
$T = 50{,}000$ lbs.

Calculate t_1 and t_2.

Solution :

$$e = \frac{M}{T} = \frac{100{,}000}{50{,}000} = 2 \text{ in.}$$

$$f_1 = \frac{A_2 d}{A_1 + A_2} \text{ (from (1))}$$

$$= \frac{3 \times 10}{9} = 3\tfrac{1}{3} \text{ in.}$$

$$f_2 = \qquad 6\tfrac{2}{3} \text{ in.}$$

$$t_1 \text{ (from (3))} = \frac{50{,}000}{6} \times \frac{2 + 6\frac{2}{3}}{10}$$

$$= 7{,}200 \text{ lbs./in.}^2$$

$$t_2 \text{ (from (4))} = \frac{50{,}000}{3} \times \frac{3\frac{1}{3} - 2}{10}$$

$$= 2{,}222 \text{ lbs./in.}^2$$

Example 2 : If $d = 10$ in.
$T = 50{,}000$ lbs.

line of tension is 2 in. inside A_1.

Calculate A_1 and A_2 to give a stress of 16,000 lbs./in.² in both cases.

Solution :

$$e + f_2 = d - 2 \text{ in.} = 8 \text{ in.}$$

$$\therefore A_1 = \frac{P}{t_1} \times \frac{e + f_2}{d} \text{ from (3)}$$

$$= \frac{50{,}000}{16{,}000} \times \frac{8}{10} = 2{\cdot}5 \text{ in.}^2$$

$$A_2 = \frac{50{,}000}{16{,}000} \times \frac{2}{10} = {\cdot}625 \text{ in.}^2$$

Example 3 : $d = 10$ in.
$M = 100{,}000$ in. lbs.
$P = 50{,}000$ lbs.

It is required to design A_1 and A_2, so that the stress shall be 16,000 lbs./in.² in them both.

Clearly $e = \dfrac{M}{P} = \dfrac{100{,}000}{50{,}000} = 2$ in.

BENDING AND TENSION

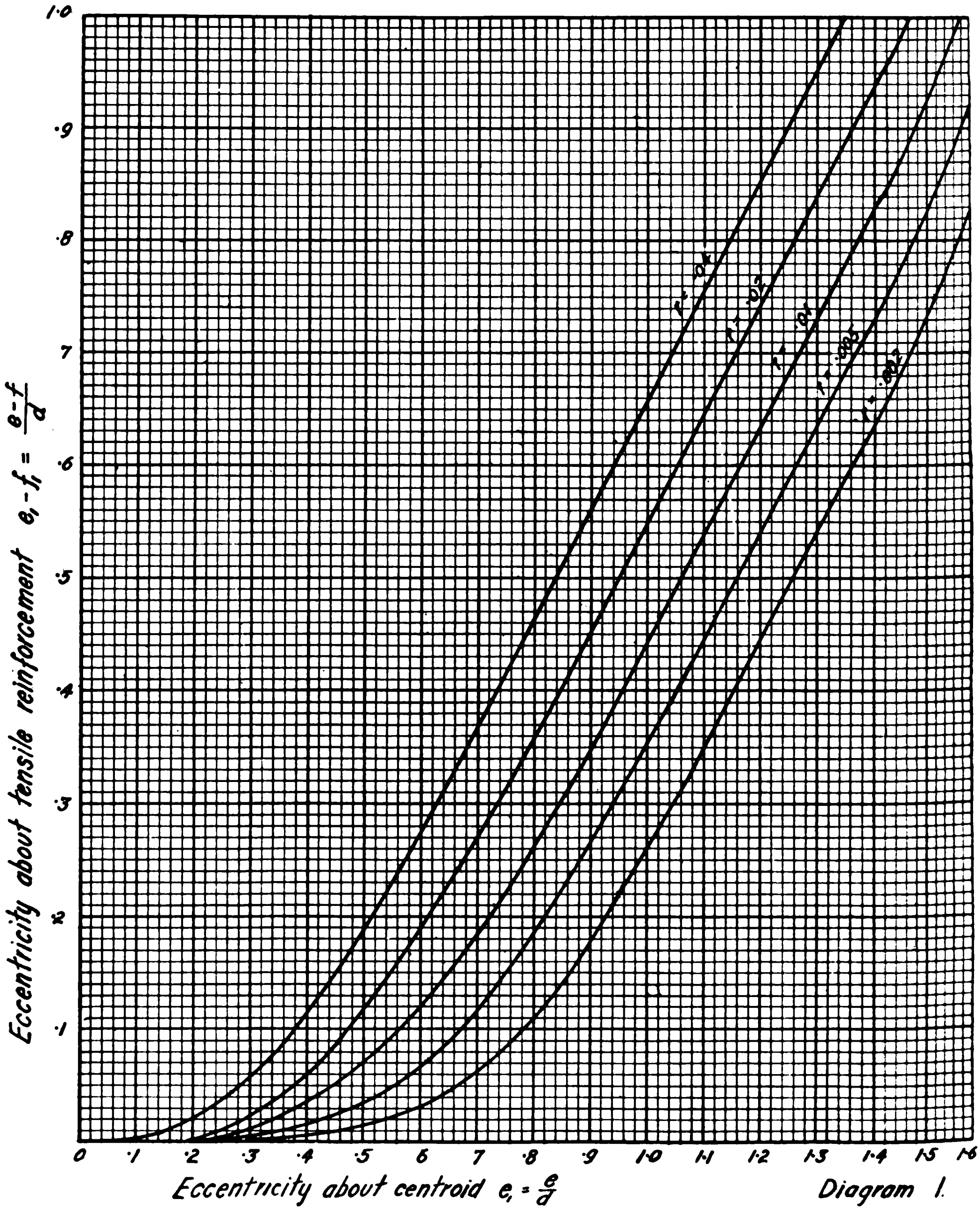


Diagram 1.

BENDING AND TENSION.

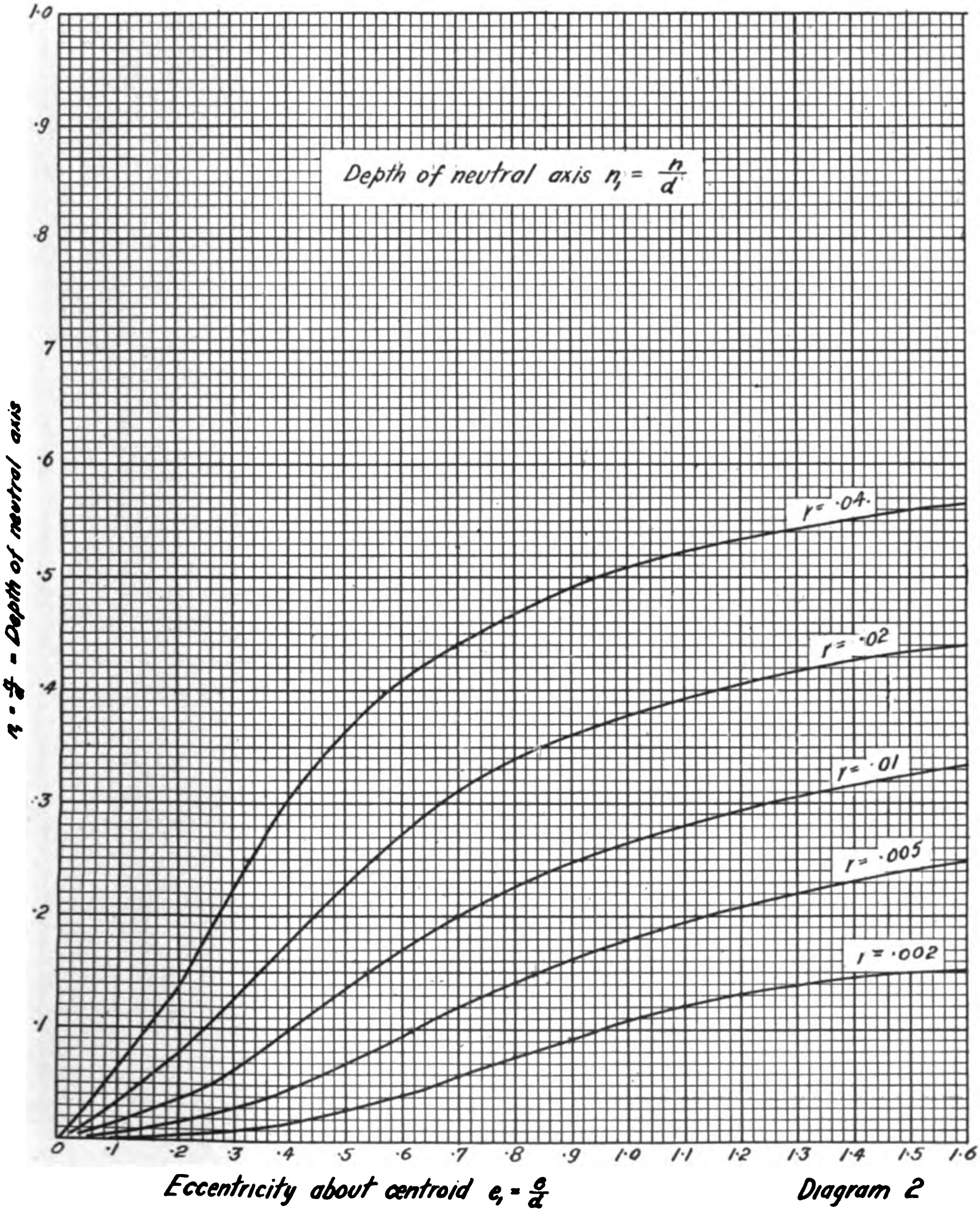


Diagram 2

Solution :

There is no solution to this question, or any similar one in which it is required to resist a moment with the same stress on both sides.

From (1) and (2)

$$\frac{f_1}{f_2} = \frac{A_2}{A_1} \text{ whence } f_1 = f_2 \cdot \frac{A_2}{A_1}$$

$$\text{Since } t_1 = t_2 \; \frac{P}{A_1} \frac{e + f_2}{d} = \frac{P}{A_2} \frac{f_1 - e}{d}$$

$$\text{whence } \frac{e + f_2}{A_1} = \frac{f_1 - e}{A_2}$$

$$\text{Substitute } f_1 = f_2 \frac{A_2}{A_1}$$

$$\frac{e + f_2}{A_1} = \frac{f_2 \frac{A_2}{A_1} - e}{A_2}$$

Multiply across

$$e A_2 + f_2 A_2 = f_2 A_2 - e A_1$$

$$e (A_1 + A_2) = 0$$

Since $(A_1 + A_2)$ cannot $\neq 0$

$$e = 0$$

In other words, there can be no eccentricity about the centroid when the stresses are equal, the centroid automatically adjusts itself then to the line of resultant tension.

Case II : When the Member is Subject to Compressive Stress on One Side and Tensile Stress on the Other—Members Singly Reinforced—Eccentricities up to 1.6d.

In *Fig.* 2 is shown a singly reinforced member subject to a tensile force P acting with an eccentricity e about the centroid $X\,X$, and producing a tensile stress t in the steel and a maximum compressive stress c in the concrete. The depth of the neutral axis (the line of no stress or strain) is n from the compressed edge, the depth of the centroid from the same point is g.

The distance of the steel from the centroid to the steel is f, while b and d are the breadth and depth of the number, the latter being, as usual, measured only to the steel from the compressed edge.

Now to start off with a given section and a given P and e and determine the remaining quantities involves very great difficulties, owing to the fact that the centroid (from which e is to be measured) cannot be determined until the neutral axis is known.

In the following treatment I have therefore tackled the subject from the back, as it were, assumed n and r the ratio of steel $\frac{A}{bd}$ which enables me to calculate $t_1 = \frac{t}{c}$, g, and f, and then to calculate what values of P and e are required to produce this condition of stress. The curves obtained from these calculations may, of course, in practice be used the other way, to determine the stresses from given values of T and e.

$$\text{Given } n_1 = \frac{n}{d}$$

$$\text{and } r = \frac{A}{bd}$$

the remaining quantities may be calculated as follows :—

Rates of stresses :

$$t_1 = \frac{t}{c} = \frac{m\,(1 - n_1)}{n_1} \quad . \quad . \quad 1$$

(See *R.C.D.*, Volume 1. m is the modular ratio.)

To obtain g, the depth of the centroid, take moments of the areas about the compressed edge. The equivalent steel area is $m\,A$ and its moment about the compressed edge is $m\,A\,d$. The area of concrete in compression is bn and its moment about the compressed edge is $bn \times \frac{n}{2}$. Hence g (which is the sum of the moments divided by the sum of the areas)

$$g = \frac{mAd + bn \times \frac{n}{2}}{mA + bn}$$

Substituting $A = rbd$ and dividing top and bottom by b, this reduces to

$$g = d\left(\frac{mr + \frac{n_1^2}{2}}{mr + n_1}\right)$$

or

$$g_1 = \frac{g}{d} = \frac{mr + \frac{n_1^2}{2}}{mr + n_1} \quad . \quad . \quad 2$$

f_1 can then be obtained as follows :—

$$f = d - g$$

$$= d - d\left(\frac{mr + \frac{n_1^2}{2}}{mr + n_1}\right)$$

$$= d\left(\frac{mr + n_1 - mr - \frac{n_1^2}{2}}{mr + n_1}\right)$$

$$= d\left(\frac{n_1\left(1 - \frac{n_1}{2}\right)}{mr + n_1}\right)$$

$$\text{or } f_1 = \frac{f}{d} = \frac{n_1\left(1 - \frac{n_1}{2}\right)}{mr + n_1} \quad . \quad . \quad . \quad . \quad 3$$

Coming now to the determination of the remaining quantities, the forces and distances can be represented as in *Fig.* 2. T and C represent the resultants of the internal tensile and compressive forces. The distance a (the radius arm) is at once determined by n, as usual.

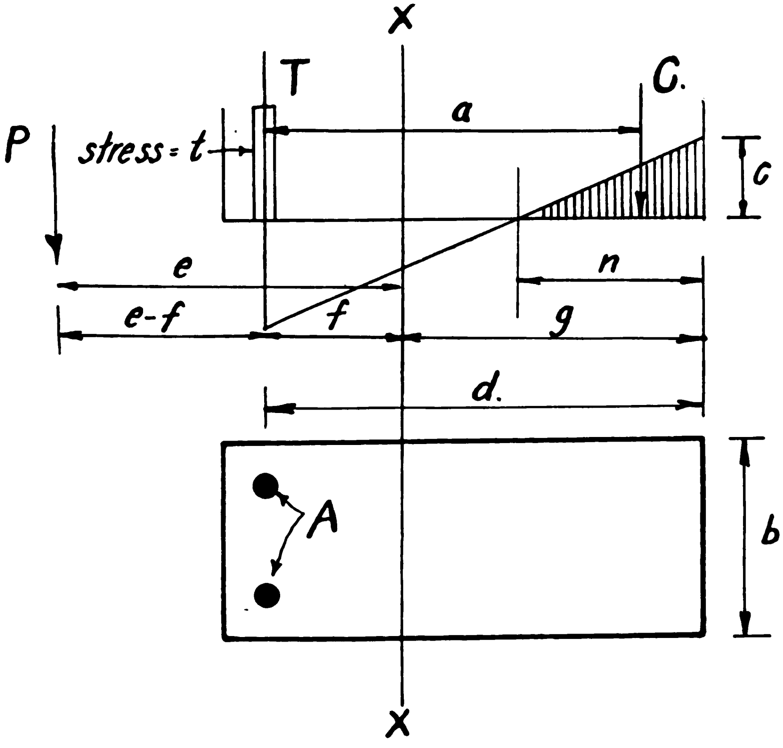


Fig 2.

$$a_1 = \frac{a}{d} = 1 - \frac{n_1}{3} \quad . \quad . \quad . \quad 4$$

Since the moments about C must balance,

$$P\,(e - f + a) = T\,a$$

Substituting $T = t\,A$ where t is the tensile stress and A the area of tensile reinforcement.

$$P\,(e - f + a) = t\,A\,a$$

$$\text{whence } t = \frac{P}{A}\left(\frac{e - f + a}{a}\right) \quad . \quad 5$$

Taking moments about T

$$P\,(e - f) = C\,a$$

$$= \frac{c}{2}\,b\,n\,a$$

$$\text{whence } c = \frac{2P\,(e - f)}{b\,n\,a} \quad . \quad 6$$

from (5) and (6)

$$t_1 = \frac{t}{c} = \frac{(e - f + a)\,bn}{2A\,(e - f)}$$

Substitute $A = r\,b\,d$

$$t_1 = \frac{(e - f + a)\,n}{2r\,d\,(e - f)}$$

$$= \frac{(e - f + a)\,n_1}{2r\,(e - f)}$$

whence :

$$(e - f)\,2rt_1 = (e - f)\,n_1 + a\,n_1$$

$$(e - f)\,(2rt_1 - n_1) = a\,n_1$$

BENDING AND TENSION

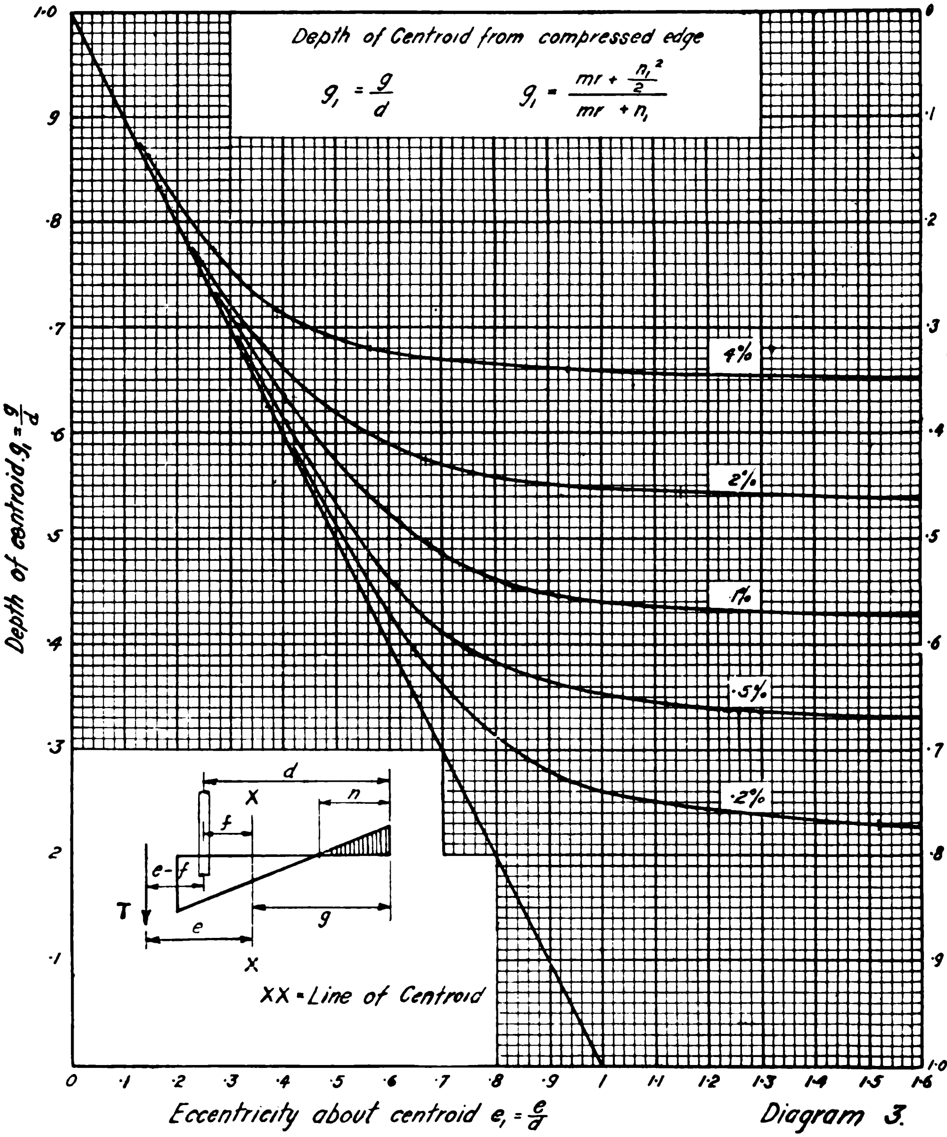


Diagram 3.

BENDING AND TENSION.

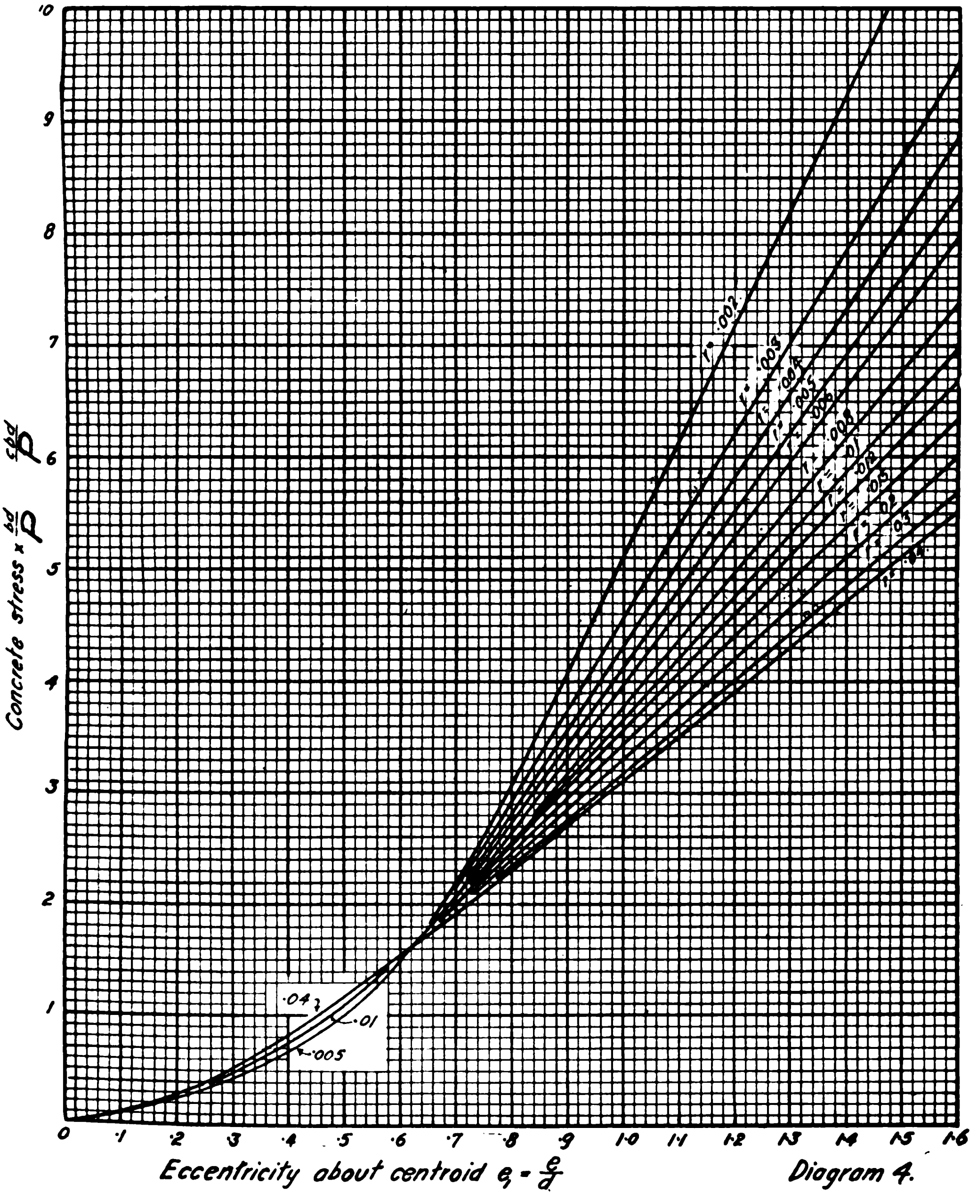


Diagram 4.

$$e - f = \frac{a\,n_1}{2\,r\,t_1 - n_1}$$

$$\frac{e - f}{d} = e_1 - f_1 = \frac{a_1 n_1}{2r\,t_1 - n_1} \quad . \quad 7$$

It now only remains to express the stresses in terms of P and $b\,d$. This may be done as follows. Referring back to *Fig.* 2, it is clear that the sum of the downward forces must balance the upward force, so that

$$P = T - C$$

whence

$$\frac{P}{bd} = \frac{T}{bd} - \frac{C}{bd}$$

Substituting $T = r\,bdt$

and $C = n\,b\frac{c}{2} = n_1\,b\,d\,\frac{c}{2}$

$$\frac{P}{b\,d} = \frac{r\,b\,d\,t}{bd} - \frac{n_1\,b\,d\,\frac{c}{2}}{bd}$$

$$= rt - \frac{n_1 c}{2}$$

$$= rt - \frac{n_1}{2}\frac{t}{t_1} \text{ since } t_1 = \frac{t}{c}$$

$$= t\left(r - \frac{n_1}{2t_1}\right)$$

whence

$$\frac{t\,bd}{P} = \frac{t_1}{r\,t_1 - \frac{n_1}{2}} \quad . \quad . \quad . \quad 8$$

and

$$c\,\frac{b\,d}{P} = \frac{t}{t_1}\frac{bd}{P}$$

$$= \frac{1}{t_1}\cdot\frac{t_1}{rt_1 - \frac{n_1}{2}}$$

$$= \frac{1}{rt_1 - \frac{n_1}{2}} \quad . \quad . \quad . \quad 9$$

From these equations it is therefore easy to calculate all the quantities corresponding to an assumed value for r (the steel ratio), and n_1 (the depth of neutral axis). Perhaps an example will be worth while.

Take the case of 1 per cent. steel ($r = \cdot 01$) and $n_1 = \frac{n}{d} = \cdot 3$.

Then

$$a_1 = 1 - \frac{n_1}{3} \text{ (Eqn. 4)}$$

$$= \cdot 9$$

$$g_1 = \frac{mr + \frac{n_1^2}{2}}{mr + n_1} \text{ (Eqn. 2)}$$

$$= \frac{\cdot 15 + \cdot 045}{\cdot 45} = \cdot 4325$$

$$f_1 = 1 - g_1 = \cdot 5675$$

$$t_1 = \frac{m(1 - n_1)}{n_1} \text{ (Eqn. 1)}$$

$$= \frac{15 \times \cdot 7}{\cdot 3} = 35$$

From (Eqn. 7)

$$(e_1 - f_1) = \frac{a_1 n_1}{2rt_1 - n_1} = \frac{\cdot 9 + \cdot 3}{\cdot 02 \times 35 - \cdot 3} = \frac{\cdot 27}{\cdot 7 - \cdot 3}$$
$$= \cdot 675$$

$$\therefore\ e_1 = (e_1 - f_1) + f_1 = \cdot 675 + \cdot 5675 = 1\cdot 2425$$

$$\frac{tbd}{P} = \frac{t_1}{rt_1 - \frac{n_1}{2}} \text{ (Eqn. 8)}$$

$$= \frac{35}{\cdot 35 - \cdot 15} = \frac{35}{\cdot 2} = 175$$

$$\frac{cbd}{P} = \frac{1}{rt_1 - \frac{n_1}{2}} \text{ (Eqn. 9)}$$

$$= \frac{1}{\cdot 35 - \cdot 15} = \frac{1}{\cdot 2} = 5$$

These calculations give us a point on one curve on each of diagrams 1 to 6. It will be understood that to produce many points on many curves requires a good deal of spade work, but only by this means could the curves be drawn. The results are here recorded for future reference in tabular form.

Diagrams 1 to 6 set these results out in the form of curves which will be found of great convenience in design, but which also bring out some very interesting facts. When there is no eccentricity, the member is clearly subject to pure tension, and the steel is the centroid.

Diagram 1 shows how, when a slight eccentricity occurs, the centroid moves rapidly away from the steel. Thus, when the external tension moves from the steel to a point ·1 *d* outside it, the centroid moves a distance of ·68 *d* the other way (with a steel percentage of ·5) making the actual eccentricity ·78 *d*. This effect is most marked for small eccentricities.

A comparison of Diagrams 2 and 3

shows how the neutral axis and the centroid, starting from the tensile and compressive edges respectively with $e_1 = o$ gradually approach one another, and coincide when e_1 becomes great.

Diagram 4 brings out the interesting fact that at an eccentricity of about ·62 *d*, the concrete stress is independent of the steel percentage. It must be remembered, however, that this eccentricity of ·62 *d* from the centroid corresponds to very different eccentricities from the steel reinforcement, as will be seen by reference to Diagram 1, which gives the corresponding eccentricities from the steel as varying from ·29 *d* for 4 per cent. steel, to ·036 *d* for ·2 per cent. steel.

TABLE I.—BENDING AND TENSION.

Steel Ratio. r	Depth of Neutral Axis. n	Radius Arm. a	Depth of Centroid g_1	Centroid from Steel. f_1	Eccentr. about Steel $e - f$	Eccentr. about Centroid e	Ratio of Stresses. $\frac{c}{t} = \frac{1}{t_1}$	Steel Stress $\times \frac{bd}{P}$ $\frac{t\,b\,d}{P}$	Concrete Stress $\times \frac{bd}{P}$ $\frac{c\,b\,d}{P}$
·002 ..	·15	·95	23	77	·749	1·519	·01175$\frac{1}{2}$	895	10·5
	·1	·96	27	·73	·219	·949	·0074	614	4·55
	·05	·98$\dot{3}$	·392	·608	·044	·652	·00351	523	1·83
·005 ..	·2	·9$\dot{3}$	·345	·655	·46$\dot{6}$	1·122	·01$\dot{6}$	300	5
	·1	·96	·457	·543	·072	.615	·0074	216.$\dot{6}$	1 6
	·05	·98$\dot{3}$	·61	39	·0175	·4075	·00351	201	·704
·01 ..	·3	·9	·4325	·5675	·675	1·2425	·028$\dot{6}$	175	5
	·2	·9$\dot{3}$	·485	·515	18$\dot{6}$	701$\dot{6}$	·01$\dot{6}$	120	2
	·1	·9$\dot{6}$	·6345	·3655	·037	4025	·0074	104	·769
·02 .	·4	·8$\dot{6}$	·5429	·4571	·69$\dot{3}$	1·15	·0445	90	4
	·3	·9	575	·425	·2455	·6705	·0286	63·6	1·82
	·2	·9$\dot{3}$	·64	36	·085	·445	·016	54·5	·9$\dot{1}$
	·1	·9$\dot{6}$	·7625	·2375	·0182	·2457	·0074	50.9	·377
·04 ..	·55	·81$\dot{6}$	·653	·347	1·035	1·382	·081$\dot{3}$	56·5	4·625
	·5	·8$\dot{3}$	·659	·341	·595	·936	·066	42·8	2·86
	·4	·8$\dot{6}$	·68	·32	·247	·567	·0445	32·1	1·43
	·3	·9	·717	·283	108	·391	·0286	28	·8
	·2	·9$\dot{3}$	·775	·225	·045	·27	·01$\dot{6}$	26·1	·435
	·1	·9$\dot{6}$	·864	·136	·009	·145	·0074	25·3	187

Diagram 5 shows that for small eccentricities up to about ·4 *d* the steel stress is almost unaffected.

Diagram 6 shows that the ratio of stresses $\frac{c}{t}$ increases from *o* with no eccentricity and ultimately with increasing eccentricity the curves become asymptotic to the ratio of stresses corresponding to the particular percentage of steel in pure bending.

A few examples of the use of the curves will now be given.

EXAMPLE 1 :

A reinforced beam

having $d = 10$ in.
$b = 6$ in.
$A = \cdot 614$ in.

is subject to a tension of 6,000 lbs. and a moment of 60,000 in. lbs.

The steel ratio is

$$r = \frac{2 \times \cdot 307}{10 \times 6} = \cdot 0102$$

and the eccentricity is

$$e = \frac{M}{P} = \frac{60{,}000}{6{,}000}$$
$$= 10 \text{ in.}$$

whence

$$e_1 = \frac{e}{d} = \frac{10}{10} = 1$$

Hence from Diagram 5

$$\frac{tbd}{P} = 145$$

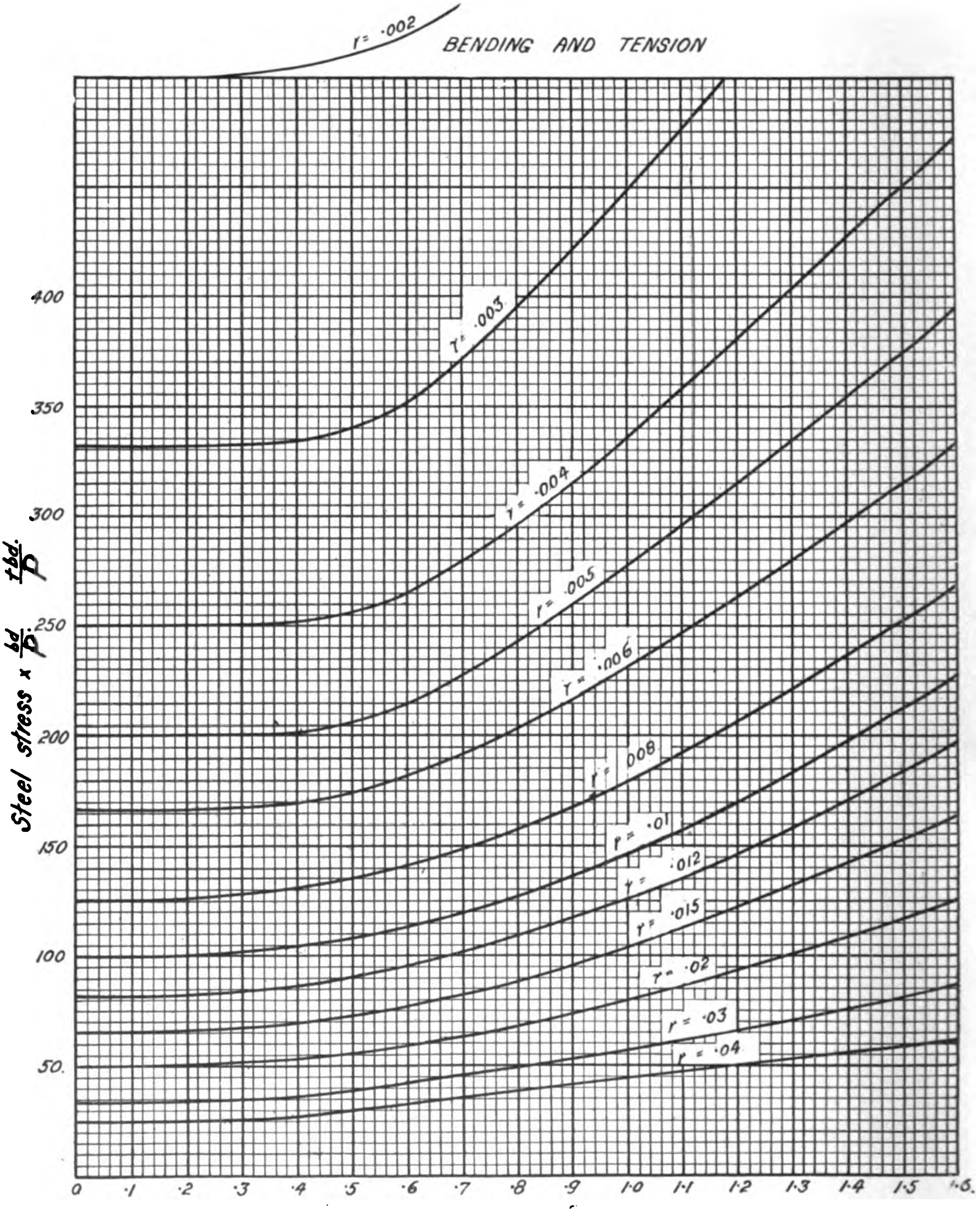
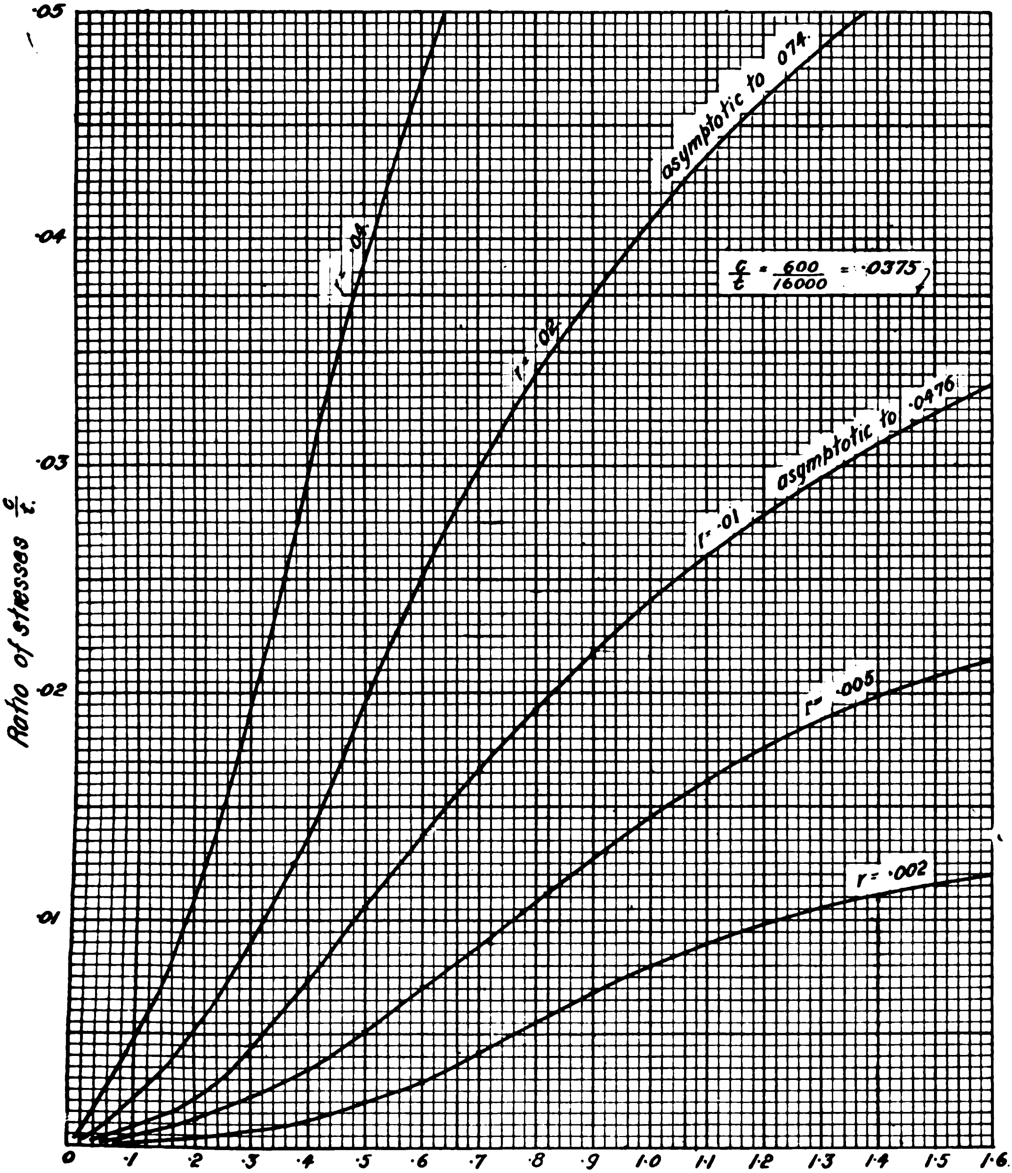

BENDING AND TENSION
r = ·002
r = ·003
r = ·004
r = ·005
r = ·006
r = ·008
r = ·01
r = ·012
r = ·015
r = ·02
r = ·03
r = ·04
Steel stress × $\frac{bd}{P}$ $\frac{tbd}{P}$
400
350
300
250
200
150
100
50.
0
·1
·2
·3
·4
·5
·6
·7
·8
·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6.
Eccentricity about centroid $e_1 = \frac{e}{d}$

Diagram. 5.

BENDING AND TENSION



Eccentricity about centroid $e_1 = \frac{e}{d}$

Diagram. 6.

and the tensile stress

$$t = 145\,\frac{P}{bd}$$

$$= 145 \times \frac{6{,}000}{6 \times 10}$$

$$= 14{,}500 \text{ lbs./in.}^2$$

From Diagram 4

$$\frac{cbd}{P} = 3{\cdot}64$$

Whence the concrete stress

$$c = 3{\cdot}64 \times \frac{P}{bd}$$

$$= 3{\cdot}64 \times \frac{6{,}000}{6 \times 10}$$

$$= 363 \text{ lbs./in.}^2$$

If the other quantities are of interest,

n (from Diagram 2) $= 2{\cdot}66$ in.
g (from Diagram 3) $= 4{\cdot}4$ in.
f $= 5{\cdot}6$ in.

Eccentricity from steel

$$e - f = 10 - 5{\cdot}6 = 4{\cdot}4 \text{ in.}$$

When it comes to design, the curves so far referred to can only be used by a tedious process of trial.

Diagram 7 has been prepared to enable a section to be calculated direct.

Its derivation is as follows :—

From Diagram 4 we have values for $\dfrac{cbd}{P}$

Now

$$\frac{c}{\dfrac{cbd}{P}} = \frac{P}{bd}$$

So that if we divide a safe concrete stress (such as 600 lbs./in.²) by the values $\dfrac{cbd}{P}$ given in Diagram 4, we obtain a safe value of $\dfrac{P}{bd}$ in which c will be 600.

Similarly, if we divide a safe tensile stress t (such as 16,000 lbs./in.²) by the values of $\dfrac{tbd}{P}$ given in Diagram 5, we obtain a safe value of $\dfrac{P}{bd}$ in which t will be 16,000.

In this way we obtain two values for $\dfrac{P}{bd}$ for a given steel ratio and eccentricity, one of which limits the concrete stress to 600 and the other limits the steel stress to 16,000.

By selecting the lower value, we ensure that *neither* the safe compressive nor tensile stresses will be exceeded.

Thus, for $r = {\cdot}01$ and $e = 1{\cdot}2425$ we have from Table I (or Diagram 4)

$$\frac{cbd}{P} = 5$$

$$\frac{P}{bd} = \frac{c}{\dfrac{cbd}{P}} = \frac{600}{5} = 120$$

when $c = 600$.

Similarly

$$\frac{tbd}{P} = 175$$

$$\therefore \frac{P}{bd} = \frac{t}{\dfrac{tbd}{P}} = \frac{16{,}000}{175} = 91{\cdot}5$$

when $t = 16{,}000$.

Hence, if we take $\dfrac{P}{bd} = 91{\cdot}5$ we shall have a steel stress $= 16{,}000$ and a concrete stress under 600.

In this way the values in Table II and Diagram 7 have been prepared and are here recorded. It should be noted that in the Table the higher (and therefore unrequired) figures are not recorded.

An example of design with Diagram 7 will now be given.

EXAMPLE 2 : A beam has to carry a direct tension of 20,000 lbs. and a moment of 100,000 in. lbs. Select a suitable section for maximum stresses not to exceed 600 and 16,000.

Solution : Take

$$d = 20 \text{ in.}$$

$$e = \frac{M}{P} = \frac{100{,}000}{20{,}000} = 5 \text{ in.}$$

Then

$$e_1 = \frac{e}{d} = {\cdot}25$$

Hence, from Diagram 7, with $r = {\cdot}01$,

$$\frac{P}{b\,d} = 158 \quad b = \frac{P}{158d} = \frac{20{,}000}{158 \times 20}$$

$$= 6{\cdot}35 \text{ in.}^2$$

Area of steel

$${\cdot}01 \times 20 \times 6{\cdot}35 = 1{\cdot}27 \text{ in.}^2$$

TABLE II.—BENDING AND TENSION.

Safe values of $\frac{P}{bd}$ for limiting stresses of $c = 600$; $t = 16{,}000$.

$r = \cdot 002$			$r = \cdot 005$			$r = \cdot 01$			$r = \cdot 02$			$r = \cdot 04$		
e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600
1·519	17·0		1·122	53·3		1·2425	91·5		1·15		150	1·382		129·5
												·936		210
·949	26·1		·615	74		·7016	133·3		·6705	252		·567		420
												·391	572	
·652	30·6		·4075	79·6		·4025	154		·445	294		·27	614	
												·145	633	
						0			·245	315		0	640	
							160		0	320				

Clearly alternative solutions with other depths and percentages can readily be calculated with ease from the diagram.

Case III: When e exceeds 1·6.

For the sake of accuracy and clearness, the range of the curves was limited to e_1 up to 1·6.

Beyond this, the stresses due to moment so far outweigh those due to direct tension that it is accurate enough for most purposes to calculate the stresses due to bending only, and add $\dfrac{P}{A + \dfrac{bn}{m}}$ to the tensile stress and deduct $\dfrac{P}{Am + bn}$ from the compressive stress as the effect of the direct tension.

EXAMPLE 3: Suppose a beam having—

$d = 10$ in.
$b = 6$ in.
$A = \cdot 614$ in.

is subject to a tension of 3,000 lbs. and a moment of 48,000 in./lbs.

Then

$$e = \frac{M}{P} = \frac{48{,}000}{3{,}000} = 16 \text{ in.}$$

$$\therefore\ e_1 = \frac{e}{d} = 1\cdot 6$$

This, then, is a borderline case and can be treated as under Case III or by means of the curves.

Under Case III, $r = \cdot 0102$ ($p = 1\cdot 02$). When

$$n_1 = \cdot 42 \quad n = 4\cdot 2 \text{ in.}$$
$$a_1 = \cdot 86 \quad a = 8\cdot 6 \text{ in.}$$

∴ Total compression

$$= \frac{M}{a} = \frac{48{,}000}{8\cdot 6} = 5{,}600 \text{ lbs.}$$

$$= nb\frac{c}{2}$$

$$= 4\cdot 2 \times 6 \times \frac{c}{2}$$

$$= 12\cdot 6\, c$$

Whence

$$c = \frac{5{,}600}{12\cdot 6} = 445 \text{ lbs./in.}^2$$

$$t = \frac{5{,}600}{\cdot 614} = 9{,}120 \text{ lbs./in.}^2$$

To allow for the direct tension add to t

$$\frac{P}{\dfrac{bn}{m} + A} = \frac{3{,}000}{\dfrac{6 \times 4\cdot 2}{15} + \cdot 614} = 1{,}305 \text{ lbs./in.}^2$$

and deduct from c

$$\frac{P}{Am + bn} = \frac{3{,}000}{34\cdot 4} = 87 \text{ lbs./in.}^2$$

leaving

$$t = 9{,}120 + 1{,}305 = 10{,}425 \text{ lbs./in.}^2$$
$$c = 452 - 87 = 358 \text{ lbs./in.}^2$$

Solution (under Case II) by Diagrams:

$r = \cdot 0102 \qquad e_1 = 1\cdot 6$

From Diagram 4

$$\frac{cbd}{P} = 6\cdot 95.$$

BENDING AND TENSION
Safe tension at different Eccentricities.
Members singly reinforced.

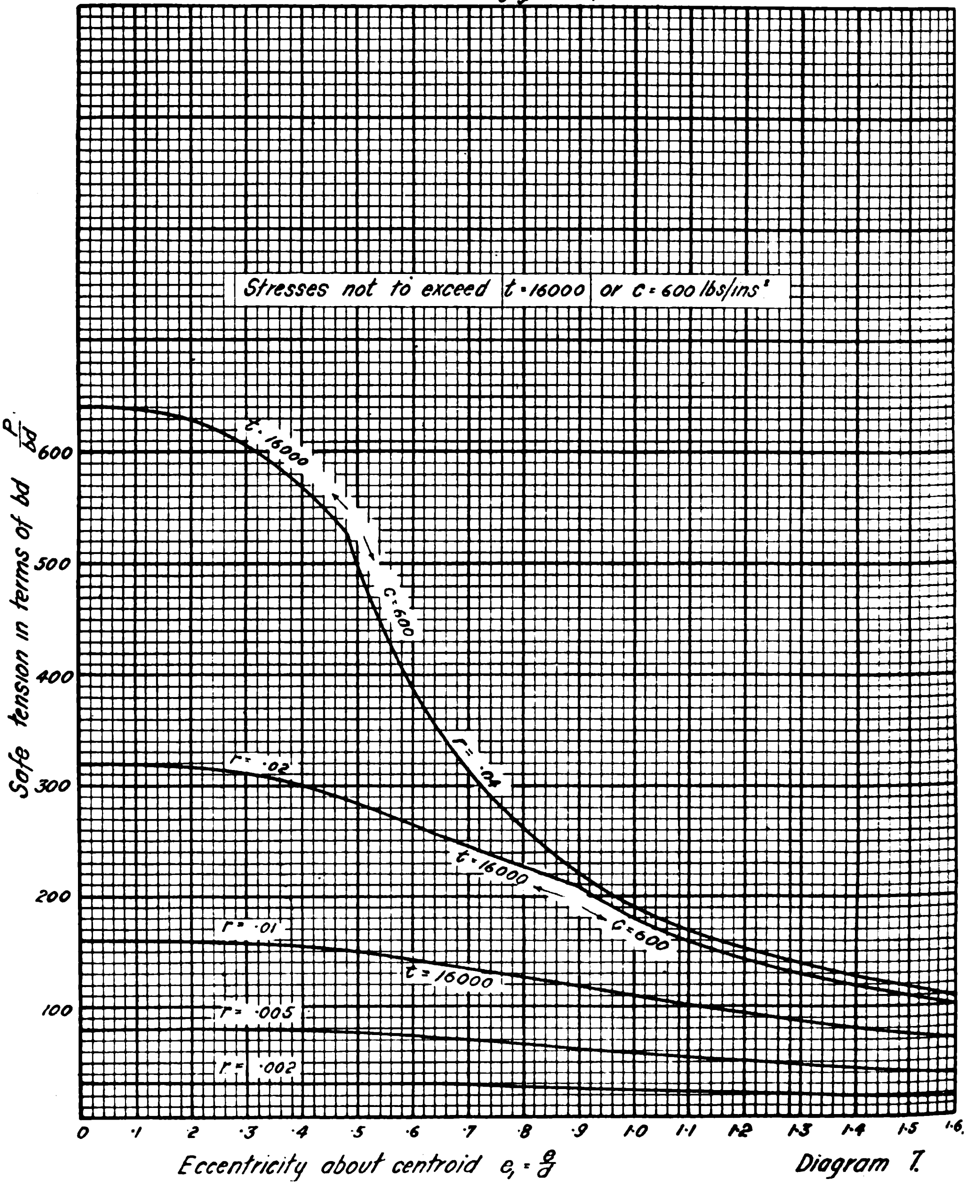


Diagram 7.

Whence

$$c = 6{\cdot}95 \times \frac{P}{bd}$$

$$= 6{\cdot}95 \times \frac{3{,}000}{6 \times 10} = 347{\cdot}5 \text{ lbs./in.}^2$$

From Diagram 5

$$\frac{tbd}{P} = 226.$$

Whence

$$t = 226 \times \frac{3{,}000}{6 \times 10} = 11{,}300 \text{ lb./in.}^2$$

It will be seen that the approximate solution does not differ badly from the accurate one by the diagrams, and as the eccentricity diminishes, this error diminishes with it.

The expression $A + \frac{b\,n}{m}$

is the equivalent area of steel plus concrete under stress expressed in steel units, and $Am + bn$ is the same expressed in concrete units.

Case IV: When Compression Reinforcement also is Provided.

The solution in this case is most readily made by considering the compressive reinforcement as increasing the strength of the compressive side, and therefore equivalent to a beam without compression reinforcement, but having increased breadth of concrete. The diagrams lend themselves readily to this. An example will illustrate the method.

EXAMPLE 4: Let us recalculate Example 1 with the addition of two ⅝-in. diameter rods in compression, 1¼ in. from the compressed edge, P being 6,000 lbs. and M 60,000 in./lbs. as before. The first thing is to select a trial value of n. As the conditions are not much altered by the compression steel, it is well to use for this the value obtained when the compression steel is neglected. This, we found from Example 1, was 2·66 in. Then we can calculate.

Total compression in concrete,

$$= nb\frac{c}{2} = 2{\cdot}66 \times 6 \times \frac{c}{2} = 8{\cdot}0\,c \text{ lb.}$$

Total additional compression due to compression steel

$$= A\,(m - 1)c \times \frac{n - 1\tfrac{1}{4} \text{ in.}}{n}$$

$$= {\cdot}614 \times 14 \times \frac{1{\cdot}41}{2{\cdot}66}c = 4{\cdot}6\,c$$

Hence the effect of the compression steel is equivalent to increasing the breadth of concrete to

$$6 \times \frac{8{\cdot}0 + 4{\cdot}6}{8}$$

$$b = 9{\cdot}45 \text{ in.}$$

The beam may now be treated as a singly reinforced beam of this breadth, when

$$r = \frac{{\cdot}614}{10 \times 9{\cdot}45} = {\cdot}0065$$

and $e_1 = 1$ as before,

whence from Diagram 2, $n_1 = {\cdot}21$
$n = 2{\cdot}1$ in.

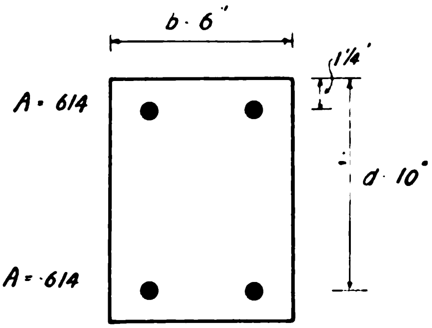


Fig 3

This differs appreciably from the assumed value of 2·66 and for great accuracy a second approximation is desirable as before.

C from concrete $2{\cdot}1 \times 6 \times \frac{c}{2} = 6{\cdot}6\,c$

c from steel ${\cdot}614 \times 14 \times \frac{{\cdot}85}{2{\cdot}1}c = 3{\cdot}46c$

Hence equivalent breadth is

$$6 \times \frac{10{\cdot}06}{6{\cdot}6} = 9{\cdot}15 \text{ in.}$$

Whence $r = \frac{{\cdot}614}{10 \times 9{\cdot}15} = {\cdot}00673$

and n, from Diagram 2, is 2·15, which agrees well enough with the previous value 2·1.

Then from Diagram 4, $\frac{cbd}{P} = 3{\cdot}92$.

Whence

$$c = \frac{3{\cdot}92 \times 6{,}000}{9{\cdot}15 \times 10} = 257 \text{ lbs./in.}^2$$

From Diagram 5, $\frac{tbd}{P} = 215$.

Whence

$$t = 215 \times \frac{6{,}000}{9{\cdot}15 \times 10} = 14{,}000 \text{ lbs./in.}^2$$

Comparing these results with those of Example 1 for the beam unreinforced in compression (363 and 14,520), it will be seen that the effect is small, especially on the tension side, as might have been expected.

Case V: When, Instead of the Moment or Eccentricity Being Given, the Position or Resultant Tension is Given.

In this case, the eccentricity can at once be found from Diagram 1, and the procedure is then as before. In cases when $e_1 - f_1$ exceeds 1 and the case is off the curves, e may be taken as $(e - f) + (d - n)$, its correct value for pure bending, n being the depth of neutral axis for pure bending corresponding to the particular steel ratio.

(*To be continued.*)

Book Review.

"Empire Municipal Directory and Year Book."

London: Published by *Municipal Engineering*. Price 10*s.* 6*d.* net.

For forty-four years this reference book has been at the service of those interested in the activities of local authorities throughout the British Empire, and obviously no effort has been spared to make the 1926 edition (just published) more comprehensive than any of its predecessors. Complete alphabetical lists are given of every local authority, with the addresses of the offices of the different services, the names of all officials, and much other useful information; for the accuracy of the information contained in these sections we can vouch from our own experience. The Year Book section contains articles on a number of phases of the work of local authorities, such as public lighting, water, electricity, and gas supply, sewage disposal, etc.

Some Lessons from Practical Experience.

By MAJOR JAMES PETRIE, O.B.E., PP.I.Struct.E.

At a meeting of the Institution of Structural Engineers on June 3, Major James Petrie gave an address particularly addressed to the younger members on Some Lessons from Practical Experience with special reference to Railway Structures. In the course of his remarks he said there were a large number of faults and pitfalls of which young engineers should steer clear, and he would try to enumerate some of them.

Foundations.—He was taught, and had followed that teaching throughout his career, to test the ground thoroughly, more especially where heavy loads had to be carried. All heavy load points should be thoroughly tested, first by boring, second, when the trenches, etc., had been excavated to the required depth, by means of long heavy steel bars driven into the earth. Where it had not been possible to test by boring, he had found the latter method very successful. After the trenches, etc., had been excavated he had by this method often found pot holes, some very bad ones, and if they had not been located the stability of the building would have been endangered. Too much care could not be exercised on the suitability of foundations to carry heavy loads.

As regarded grillage foundations on bad ground, many engineers erred on the side of designing their grillages too small. It was far safer to design the grillage with a little larger area than otherwise. He had come across cracks in buildings, bridges, etc., owing to the grillage not being large enough for the weight it was to carry. He could hear some member saying, " That is all very well where you have plenty of room to spread out: what am I to do in a confined space ? " He would reply that he would put a grillage in over the full extent of the area. He had come across a number of cases where advantage had not been taken of covering the full area. Further, the grillage itself was in a number of cases constructed of too light material, and this, in his opinion, was the cause of many failures ; it was far better and safer to design a grillage rather over than under for the weight it had to carry. Do not design a single-tier grillage ; it should never be of less than two tiers. When he had had a single-tier grillage shown on the drawings he had ignored the drawings and constructed one of two and sometimes three tiers.

As was well known, one could support heavy loads entirely on a hard crust overlaying strata of a soft nature, providing the grillage were properly designed. Do not rely upon text-books altogether. They were useful as a guide, but foundations and sites varied considerably, and every one must be dealt with accordingly. He erected a large locomotive shed to stable about 30 engines, with a large water tank containing 60,000 gallons, over the offices at one corner of the buildings—weight of water about 268 tons. The ground was marsh land, with water level at 3 ft. below ground level ; the turf was stripped, a layer of concrete 6 in. thick laid, reinforced with heavy wire lattice ; then another layer of concrete 6 in. thick reinforced again with heavy wire lattice, with a finishing layer of concrete 3 in. thick, a total thickness of 15 in. of concrete. This building was erected about 17 years ago, and there was no semblance of a crack in any part of the building. The drawings showed one layer of wire lattice only, to be fixed in the centre, but he prevailed upon the engineer to have two layers.

Piling.— Great care should be taken as regarded the completion of the driving. On the renewal of a number of bridges in Sussex, where the peat varied from 40 to 50 ft. in depth, it was found upon driving the piles that there was a strata of fine gravel about 3 ft. in depth underlying the peat, but under the gravel was another layer of peat some 2 to 3 ft. in depth, then another layer of gravel. When driving the first of the piles, which were 60 to 70 ft. in length, the pile was driven into the first bed of gravel and appeared tight after 12 blows to the inch. He was not altogether satisfied, so had the blows increased to from 25 to 30 to the inch. After the first few inches the pile went down fairly easily, each blow sending it down about 3 in., until the bottom strata of gravel was reached, where it took 30 to 40 blows to send the pile down 1 in. He then decided that was good enough, and it gave a guide for the depth for the remaining piles. The heads of the piles were cut off to the height shown on the drawings, the peat excavated to a depth of 2 ft. below the head of the pile, the concrete foundations put in to a height of 18 in. above the pile head, 3 ft. 6 in. thickness in all, and the brick abutment erected thereon. There was no sign of fractures or cracks in the brickwork in any of the bridges. The bridges were renewed about 18 years ago.

Years ago it was the practice to cut down the piles to a given level, fix planking the full length, and another layer of planking crosswise or the full width, then erect the brickwork upon same. That was, in his opinion, an unsound or bad method of construction ; to his mind, the only proper and sound method was to excavate the ground to a certain depth below the top of the pile and lay in the concrete foundation to carry the brickwork or masonry similarly to the work done on the bridges mentioned previously.

To illustrate this : he had a brick viaduct of 10 arches in length ; the pier carrying the two centre arches was gradually sinking, and this had been going on for some years before he took over the district, so he determined he would find out if possible the cause of the sinking. He had the foundations of the pier exposed. The pier was in the centre of a small stream and the foundations were always covered with water ; there was a double row of timber piles, covered with two thicknesses of 4-in. planking laid as before described. The planking had rotted between the piles, and in consequence the pier gradually settled down between the two rows of piles, leaving the footings high and dry on the planking on the top of the piles. The pile heads were cut down to 3 ft., rotten planking removed, ground excavated to a depth of 2 ft. below the top of the pile, filled in with concrete to the top of the pile, a layer of heavy wire mesh laid thereon, and a further layer of concrete to within 6 in. of the bottom of the brick pier, the whole being completed with 6 in. of brickwork. Three piers were reconstructed in the same manner. The space between piers was excavated, a concrete slab reinforced with heavy wire mesh, 18 in. thick, laid to a sweep which formed an inverted arch between the piers.

When underpinning, do not finish with slate ; it was fatal ; a good job could not be made. Use cement, well rammed home with a wooden tool, 3 in. wide, shaped like the scraper a navvy used to clean his shovel.

As regarded screw piles, he was no lover of them, and had only used them on one occasion, viz., on the south coast for the extension of a station building. They were unreliable at the screw end ; several of them broke off, no doubt owing to the large boulders that were encountered bedded in the chalk when screwing. Upon visiting the job one day the resident engineer informed him that he was unable to screw down several of the piles any lower, and they were some 4 ft. higher than those already screwed down. He (the speaker) therefore instructed him to test them by weighting as specified. He did so, and no movement took place. He then instructed him to increase the weight on each pile by another 20 tons. This was done, and the piles went down to within 6 in. of the height of the piles already driven. He then had the remaining piles tested with the increased weight of 20 tons, but there was no movement. No doubt the screw of the piles that were some 4 ft. higher than those previously driven had broken off, and there was no possibility of them being driven lower, but the extra test weight just did it. That was a lesson to be taken to heart from practical experience.

Concrete Houses at Dolgarrog.

We regret that in the article on the concrete houses at Dolgarrog in our April issue we omitted to give the name of the architect, Mr. A. J. White, of 55, Newhall Street, Birmingham, under whose direction this new industrial village is being carried out.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	6
Thames ballast	„	10	6
Broken brick (¾ in.)	„	11	6
Best British Portland Cement	per ton 58s. to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	„ 100s. to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn.		Wrot.	
		s.	d.	s.	d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £20 „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
5/16 in. to ½ in. Rounds	„	10	9
⅜ in. Rounds	„	11	0
¼ in. Rounds	„	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per foot cube	1	11
Do.	do.	in columns	„ „	2	1
Do.	do.	in beams	„ „	2	3
Do.	do.	in floor slabs 4 in. thick	per yard super	6	0
Do.	do.	in floor slabs 5 in. thick	„ „	7	6
Do.	do.	in floor slabs 6 in. thick	„ „	9	0
Do.	do.	in floor slabs 7 in. thick	„ „	10	6
Do.	do.	in walls 6 in. thick	„ „	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
„ 5/16 in. to ½ in.	„	21	6
„ ⅝ in. to 2⅞ in.	„	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½d.; ⅜-in. rods, 1d.; ½-in. rods, 1¼d.; ⅝-in. rods, 1½d.; ¾-in. rods, 1¾d.; ⅞-in. rods, 2d.; 1-in. rods, 2¼d.; 1⅛-in. rods, 3d.; 1¼-in. rods, 3½d. (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1d.; ⅜ in., 2d.; ½ in., 2½d.; ⅝ in., 3d.; ¾ in., 3½d.; ⅞ in., 4d.; 1 in., 4½d.; 1⅛ in., 6d.; 1¼ in., 7d. (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	„ „	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	„ „	1	1½
Do. do. as last, in narrow widths	„ „	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	„ „	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

ABERPORTH. — *Concrete Wall.* — The Cardigan C.C. proposes to spend £550 on the construction of a concrete wall along the present embankment at Aberporth.

ARMAGH.—*Houses.*—The R.D.C. proposes to construct 105 houses.

BARNSLEY. — *Houses.* — The Corporation is negotiating for the purchase of 70 acres at Ardsley Hill for a housing scheme.

BEWDLEY. — *Reservoir.* — A reservoir is to be built at Long Bank.

BIRKENHEAD. — *Houses.* — The T.C. has applied for sanction to a loan of £108,750 for the erection of 200 houses.

BISHOPS GREEN.—*Bridge.*—A scheme is being considered by the Newbury and Kingsclere R.D.C.'s for the construction of a bridge at Bishops Green Ford.

BOLDON. — *Houses.* — The S. Shields R.D.C. has applied for sanction to erect 122 houses at Boldon.

BOLTON-LE-SANDS.—*Bridge.*—A bridge is to be constructed over the Lancaster Canal at Town End.

BRISTOL. — *Houses.* — The Housing Committee proposes to erect 360 houses at Brislington.

CHELMARSH. — *Road.* — The Bridgnorth R.D.C. proposes to construct a road to Chelmarsh. The cost is estimated at £10,100.

CHESTERFIELD. — *Houses.* — The T.C. proposes to erect 51 houses, at an estimated cost of £25,000.

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CLITHEROE. — *Houses.* — The T.C. has purchased a housing site on which to erect 350 houses.

DARWEN.—*Houses.*—The Corporation is negotiating for a housing site.

DUBLIN.—*Houses.*—The T.C. proposes to construct 400 houses.

DUKINFIELD.—*Houses.*—The T.C. proposes to erect 100 houses in Clarendon Park.

ELLESMERE PORT. — *Bridge.* — The Cheshire C.C. has submitted to the M.T. plans for the construction of a bridge over the level crossing. The cost is estimated at £20,000.

FENCE HOUSES. — *Bridge.* — The L. & N.E. Railway Co. proposes to erect a bridge over the level crossing at Fence Houses, Houghton-le-Spring.

GRAVESEND. — *Houses.* — The T.C. is considering a scheme for the erection of 96 houses on the King's Farm estate.

HASTINGS. — *Concrete Groyne.* — The Corporation proposes to construct a concrete groyne. The cost is estimated at £3,500.

HAVERFORDWEST. — *Reservoir.* — The T.C. proposes to construct a reservoir.

HULL.—*Houses.*—The T.C. proposes to erect 208 houses on the West Hull site.

KENT.—*Houses.*—The C.C. has appointed a committee to negotiate with local authorities on the erection of 1,200 houses for the miners who will be employed at the Snowdown Colliery, East Kent.

LEEDS.—*Reservoir.*—The T.C. proposes to spend £4,166 in connection with the extension of Moortown Reservoir.

MANCHESTER. — *Houses.* — The Corporation has applied for a loan of £1,984,311 for the erection of 3,000 houses at Withington.

MYNYDDISLWYN. — *Houses.* — The U.D.C. has applied for sanction to erect 200 houses.

PWNGAM. — *Houses.* — The Cardiff Corporation proposes to spend £65,000 on the construction of 108 houses at Pwngam.

RICHMOND, YORKS.—*Reservoir.*—The T.C. proposes to construct a 1,000,000-gallon reservoir near the entrance to the racecourse.

ROCHDALE. — *Houses.* — The Corporation proposes to erect 200 houses in Queensway.

STOKE-ON-TRENT.—*Houses.*—The T.C. has applied for a loan for the erection of 60 houses on the Fletcher Lane site.

SUTTON.—*Houses.*—The U.D.C. has applied for permission to erect 100 houses in Ridge Road.

SWANSEA. — *Bridge.* — The G.W.R. proposes to erect a bridge over the level crossing at King's Dock.

SWANSEA. — *Houses.* — Application has been made by the T.C. for a loan of £55,414 for the erection of 120 houses at Morriston.

THAMES DITTON. — *Houses.* — The Esher & Dittons U.D.C. proposes to build 134 houses.

THORNABY.— *Houses.* — The T.C. is negotiating for a site on which to erect 100 houses.

WALLASEY.—*Houses.*—The T.C. has applied for a loan of £23,570 for the construction of 38 houses on the Belvidere Road site.

WOLVERHAMPTON. — *Houses.* — The T.C. proposes to spend £48,121 on the erection of 100 houses on the Low Hill estate.

Tenders Accepted.

ASHTON-UNDER-LYNE. — The Building Department of the Co-operative Wholesale Society, Ltd., of Lower Broughton, Manchester, has secured the contract for the concrete work in connection with the erection of an emporium at Ashton. The cost is £2,360.

BOSTON.—*Concrete Bridge.*—The Holland (Lincs.) C.C. has accepted the tender of the Yorkshire Hennebique Contracting Co., Ltd., at £20,830, for the construction of a reinforced concrete bridge at Spalding. Other tenders submitted were: Stewart & Partners, £21,017 4*s.*; F. Mitchell & Son, Ltd., £21,098; L. J. Speight, Ltd., £21,763 10*s.*; Saxild & Partners, £23,881; Purdie, Lumsden & Co., £24,440 11*s.* 4*d.*; Sir W. Prescott & Sons, Ltd., £24,889 8*s.* 5*d.*; J. Gill (Contractors), Ltd., £24,983 12*s.* 10*d.*; Walker-Weston Co., Ltd., £25,800 2*s.* 5*d.*; and Sir J. P. Gallwey, Ltd., £34,134 10*s.* 1*d.*

EARSHAM, NORFOLK.—*Concrete Cottages.*—The Depwade R.D.C. has accepted the tender of Mr. H. Blackburn, Harleston, at £3,590, for the erection of 8 concrete cottages.

GUILDFORD. — *Concrete Bridge.* — The R.D.C. has accepted the tender of Messrs. A. Streeter & Co., Godalming, at £2,757 11*s.* 11*d.*, for the construction of a reinforced concrete bridge over the River Wey.

HULL. — *Concrete Foundations.* — The T.C. has accepted the tender of Messrs. Quibell & Sons, Ltd., Hull, at £885, for concrete foundation work at the electricity works. Other tenders submitted were: Kettlewell, Son & Co., Ltd., £1,460; Hinch Bros., Ltd., £985; and H. Sugden, Son & Co., £984.

LEYBURN. — *Concrete Bridge.* — The Leyburn R.D.C. has accepted the tender of Messrs. J. Busfield, Ltd., Boar Lane, Leeds, at £606 12*s.*, for the construction of a reinforced concrete bridge at Castle Bolton Ghyll. Other tenders submitted were: G. Fordy, £953 4*s.*; Yorkshire Hennebique Contracting Co., Ltd., £938 6*s.* 6*d.*; W. V. Patrick, £931 8*s.*; J. H. Thistlethwaite, £567 4*s.*; and J. C. Cradock, £556 1*s.*

LIVERPOOL. — *Concrete Houses.* — The Corporation has recommended for acceptance the tenders of Messrs. Henry Boot & Sons, Ltd., for the construction of 2,000 concrete houses.

LLANFAIRTALHAIARN.—*Concrete Bridge.*—The St. Asaph R.D.C. has accepted the tender of Messrs. Sir W. Prescott & Son, Ltd., at £4,400, for the construction of a reinforced concrete bridge over the River Elwy.

MANCHESTER.—*Offices and Stores.*—The T.C. has accepted the tender of the Fram Reinforced Concrete Co., Ltd., for the construction of general offices, stores, etc., at Partington.

OLDHAM. — *Concrete Piling.* — The T.C. has accepted the tender of Messrs. S. & J. Smethurst, Ltd., for concrete piling work in connection with the new generating station at Oldham.

PARTNEY. — *Concrete Cottages.* — The Spilsbury R.D.C. has accepted the tender of Messrs. Baker & Webb, of Spilsby, at £845, for the erection of two concrete cottages at Partney.

PORTSMOUTH.—*Concrete Balustrades.*—The T.C. has accepted the tender of Mr. J. Croad, Portland Street, Portsmouth, at £1,728, for the construction of concrete balustrades around the gardens at Southsea Common.

WIMBLEDON.—*Concrete Houses.*—The T.C. has accepted the tender of the Triangular Construction Co., for the construction of 69 concrete houses on the Durnsford Road site.

WOOLWICH (LONDON).—*Concrete Houses.*—The B.C. has accepted the tender of Messrs. John Laing & Son, Ltd., at £238,822 19*s.*, for the construction of 500 concrete houses.

New Companies Registered.

AEROCRETE HOLDINGS, LTD. (213240). Registered April 17. To finance the Aerated Concrete Co., Ltd., and a company about to be registered under the title of "Aerocrete (Foreign), Ltd." Nominal capital, £7,500.

ALLIED CONCRETE CO., LTD. (213731). Registered May 11. High Street, Morley, Leeds. Concrete manufacturers, etc. Nominal capital, £2,000. Directors: S. Scarth, Middleton Road, Morley, Leeds; J. S. Berry, Monk Fryston, South Milford; H. Thackrah, Britannia Buildings, Morley, Leeds.

CASEBOURNE & CO. (1926), LTD. (213790). Registered May 15, 1926. Pioneer Cement Works, Haverton Hill, Durham. To take over the business of Portland Cement manufacturers and merchants carried on by Casebourne and Co., Ltd. Nominal capital, £40,000. Directors: Sir John Hunter, K.B.E., Dalmarnock Iron Works, Glasgow, chairman; A. C. Kingston, Pioneer Cement Works, Haverton Hill, Middlesbrough; H. Cunningham, Dalmarnock Iron Works, Glasgow; E. A. Hunter, Dalmarnock Iron Works, Glasgow.

TAYLOR AND HALL, Ltd. (213364). Registered April 22. Ravensbury Works, The Drive, Wandle Road, Morden, Surrey. Builders and concrete slab manufacturers. Nominal capital, £2,500. Directors: J. Taylor, "Leonora," Wandle Road, Morden; and A. A. Hall, The Bungalow, Wandle Road, Morden.

Recent Patent Applications.

250363.—W. Eccles, T. G. Williams and Metropolitan-Vickers Electric Co., Ltd.: Ferro-concrete foundations.

250446.—J. J. V. Armstrong: Means of securing hangers, etc., to reinforced-concrete structures.

250711.—F. J. Bean: Concrete buildings.

250727.—S. Rose: Casting concrete culverts *in situ*.

250745.—E. W. Brock: Concrete walls.

250761.—E. C. St. A. Newby: Building and facing concrete walls.

250800.—R. H. Kirk and H. Martiney: Casting concrete blocks.

Price 1*s.* 6*d. net.* *Annual,* *Post Free,* 18*s.*

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

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CONCRETE
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EDITORIAL NOTES.

Reinforced Concrete Regulations.

THE regulations governing the erection of reinforced concrete buildings in London came into force eleven years ago, and on their publication it became evident to those who studied them and who realised what they meant—with their one hundred and eighty odd clauses and many mathematical formulæ—that they were in many respects unsatisfactory. They have severely hindered the use of reinforced concrete construction in London, and it is a significant fact that since the introduction of these regulations nearly all the reinforced concrete buildings that have been put up in Great Britain have been erected outside the London area. The London County Council has recently indicated its intention of issuing new regulations and it is to be hoped that these, when issued, will not only be less onerous but will also be shorter in length.

The question of these regulations was brought up in an interesting form last month in the hearing before a Select Committee of the House of Lords of petitions by four technical societies against certain clauses of the London County Council (General Powers) Bill 1926. There are two matters in this Bill which are of interest in connection with the subject we are considering. The first deals with the conversion of buildings "constructed wholly or partly of reinforced concrete," and seeks to give the Council power to make regulations governing such converted buildings; it is made clear in the Bill that conversion is to cover change of user as well as structural alteration. The second seeks to give the Council power to waive any of its regulations "in order to facilitate the erection of any particular building or part of a building intended to be constructed wholly or partly of reinforced concrete."

Petitions against the bill were lodged by the Surveyors' Institution, The Institution of Civil Engineers, The Royal Institute of British Architects, and the Institution of Structural Engineers, who based their objection chiefly on the reference to buildings wholly *or partly* of reinforced concrete. The Institutions held the view that although these words occur in the clause of the Act of 1909. which gives the London County Council power to make regulations, the intention of the legislature was to restrict such regulations to reinforced concrete frame buildings in the same way that the earlier clauses of the same Act were restricted to steel-frame buildings. They pointed out that the existing regulations made under this Act were in fact so restricted, and wished to ensure that all regulations made under this practice would continue. The point is a very important one, because if a building owner erects a building with ordinary brick walls complying with the 1894 Act he can do all the floors and internal columns in reinforced concrete and ignore the reinforced concrete regulations ; he can also erect a steel-frame building with all the floors in reinforced concrete and still ignore the reinforced concrete regulations for such floors.

Mr. Charteris, who appeared as counsel for the L.C.C., read a report from H.M. Ministry of Health in which rather strong objection was made to giving power of waiver over the regulations, suggesting that regulations should be like by-laws, which cannot be modified in any case until amended. We cannot agree with this suggestion—nor was it supported by Mr. Craig Henderson who appeared for the Institutions. He, on the other hand, urged that an appeal should lie from the Council to the Tribunal of Appeal appointed under the 1894 Act, so that anyone could appeal from the refusal of the Council to grant a waiver or from the conditions under which such waiver is granted. This is an important matter, because official bodies have been known to give with one hand and take away with the other. The Council argued against this right of appeal except in matters not affecting the stability of the building, and the Committee passed the waiver clause with the provision for appeal inserted as in the 1909 Act.

In the Ministry of Health report objection was taken against the waiver practice on the ground of lack of publicity ; but the Council indicated that they had no basic objection to publication being made, and all their witnesses supported the suggestion. We think this is a move in the right direction ; the waiver practice is doubtless of great value, and if it has taken eleven years to amend the regulations when the Council has had no power of waiver it seems absurd to speak of amending by-laws as a remedy for regulations which either are unsatisfactory when they are issued or become so due to progress in science. At the present time, for instance, cement is available which will give a compressive stress of over 5,000 pounds per square inch in three months for a 1 : 2 : 4 mix, and yet we are only allowed to stress it up to 600 pounds per square inch ; nor will the authorities be empowered to alter this unless they have the power of waiver. The advantage of publicity will be that we shall be able to see what has been allowed, and therefore we shall be able to proceed in the assurance that a similar allowance will be repeated.

On the question of the clause dealing with conversion of buildings, Mr. Topham Forrest, F.R.I.B.A., Architect to the L.C.C., said in cross-examination that the Council did not intend this to apply to steel-frame buildings or to 1894 Act buildings ; this met to a large extent the objection of the Institutions to the clause, and their counsel asked for the clause to be revised so as to make this clear. The Committee, however, passed the clause without amendment.

We expressed the view earlier in this article that the existing London County Council Regulations for Reinforced Concrete had made it difficult to erect reinforced concrete buildings in London. This was frankly admitted by one of the witnesses who was called by the London County Council in support of the Bill: he agreed that the 1915 Regulations have, in fact, very much hampered the building in London in reinforced concrete. We hope that the Council will see to it that when they issue their revised regulations they will do something to encourage the form of construction which the existing regulations have hampered. A report of the hearing of the petitions is given on p. 526.

A Note on the Various Methods of

Gauging the Constituents of Concrete.

By E. FIANDER ETCHELLS, A.M.Inst.C.E., A.M.I.Mech.E., M.I.Struct.E.

THE purpose of this article is to discover the best methods of gauging the constituents of concrete. The term " to gauge " means " to find the measure of some quantity." The " measure " of any given quantity is the number of unit quantities contained in that given quantity.

The term " measure " is therefore applicable to quantities of all kinds, and not only to those quantities which can be measured in units of length, such as the inch, foot, yard, or metre. Having given a definite meaning to the word " measure " when used as a technical term, we are now in a position to consider the major question.

What is the best method of gauging the constituents of concrete? The question seems to be simple enough; nevertheless it cannot be answered unless there be some information as to the circumstances of the measurement. If such measurements are to be made on the small quantities of materials necessary to make a few test cubes in a laboratory, then there is no doubt that the amount of all the constituents should be determined by weight alone.

The measurement of cement, sand, or coarse material by a comparison of volumes is much too crude a method for laboratory use. Let the reader take any convenient receptacle, fill it loosely with dry cement, and then let the contents be shaken down. The quantity of cement remains the same, but the volume occupied may be only 80 per cent. of the former volume. Again, a cartload of sand may be loaded at the sand pit, but at the end of a long journey over a rough road there will be less than a cart full, even if none has been spilt or lost on the way.

This much is obvious, but nevertheless persons responsible for the execution of concrete work sometimes overlook one of the consequences of this fact—namely, that the volume of loose materials is not always a reliable indication of the quantity of such loose materials. The volume occupied by a ton of gravel may vary within wide limits.

So far we have only spoken of exactness of measurement, but in all large building contracts other questions obtrude themselves; and the question of relative economy is never absent. Consequently methods appropriate in the laboratory may be entirely out of place in large-scale operations in the field or on the site of a building. It therefore follows that some other method of specifying the amount of the various constituents must be found. Some of these methods will be discussed, and finally it is proposed to describe the method which, at the present time, appears to possess the maximum of advantages and the minimum of disadvantages.

Before doing so, however, it will be necessary to give precision to the description by defining two or three technical terms which are used in different senses by different writers:

The term " aggregate " means any mixture of approved coarse materials plus sand. The term " aggregate " should never be used to denote the coarse material alone. Now let us turn to the cement. In this country, Portland cement is usually sold in bags containing about 204 lbs. Eleven bags would therefore weigh 11 + 204 lbs. (2,244 lbs.). Therefore there are eleven bags per ton. When the term " bag of cement " is used without any other qualifying phrase it must be taken as denoting the whole contents of a sack or bag, which contains approximately 204 lbs. of Portland cement.

We are now in a position to contrast various modes of specifying the proportions of concrete. The first method to be noted is that of specifying the number of bushels of cement to be mixed with each cubic yard of aggregate. This method is occasionally employed to-day by elderly gentlemen having obviously antiquarian tastes. To such dear delightful supporters of mediæval customs, the ordinary Portland cement, which is only about a hundred years old, must seem like a newfangled material. This method is seen in its most precise form when the amount of cement is specified in " striked bushels." This method need only be mentioned to be dismissed as a lagging survival, which has lagged too long, upon that stage where concrete is mixed and made.

The second method consists in specifying the ratio of volumes. For example, the expression " a five to one concrete " means that five cubic feet of aggregate are to be mixed with one cubic foot of cement. The defects of this method are :

(*a*) a cubic foot of cement is not a fixed amount, but varies with the degree of consolidation.

(*b*) Cement is not sold by the cubic foot.

The third method consists in specifying the pounds of cement per cubic yard of aggregate. This method has two advantages.

(*a*) Cement is sold by weight, and the amount to be used is specified by weight.

(*b*) Aggregate is usually sold by volume and the amount to be used is specified by volume.

The method has, however, one disadvantage of a mathematical character. This disadvantage is most apparent to those who endeavour to plot the various crushing resistances of the concrete for each value of that rate which is weight of cement per volume of aggregate. In the case of neat cement, this rate is infinite, and such values are not suitable for practical work.

The fourth method consists in specifying the pounds of cement per cubic yard of finished concrete. This method is suitable for laboratory use and for the preparation of graphs, but it is of little assistance to builders in the preparation of estimates and the submission of tenders. The difficulty consists in the introduction of variables which cannot be known until the concrete has been made up in bulk under working conditions. The volume of finished concrete which will result from mixing a definite weight of cement with a stated volume of gravel, which has not yet been excavated and tested, is not a known quantity, and the difference between the guess and the fact may make all the difference between a profit and a loss.

The fifth method, which has more advantages and less disadvantages in practical work, consists in specifying the cubic feet of aggregate per bag of cement. This method will suit the contractor because

(*a*) The aggregate can be sold by volume and the amount to be used is specified by volume.

(*b*) The cement is sold by weight and the amount to be used is specified by weight, with the bag as a very convenient unit.

In the case of neat cement, that rate which is volume of aggregate per bag of cement has the numerical value of zero, and this is quite convenient in preparing graphs showing the crushing resistance of concrete made with varying volumes of aggregate per bag of cement.

There is another merit of the fifth method, but this particular merit cannot be explained unless one is familiar with the simplest standard method of describing any kind of a rate. A rate is the measure of an apportionment of two separate quantities. For example one may speak of weight per volume, or weight per area, or weight per length, or distance per time. In all the above cases the presence of the word " per " is an indication of the existence of a rate. A rate cannot be described unless two separate quantities are specified. The first quantity is called the " antecedent " and the second quantity is called the " consequent."

A rate is reduced to its simplest form whenever the " consequent " is a unit quantity. For example, a rate of 60 miles per two hours is the same rate as 30 miles per one hour, or, more simply still, 30 miles per hour. Similarly one may speak of a rate of 60 shillings per week, or a rate of 60,000 tons of cement per year. Now the rate of " so many cubic feet of aggregate per bag of cement," has a unit quantity for its antecedent, namely a bag of cement. It is therefore given in that form which, by universal consent, is regarded as the simplest of all.

After actual trial of this particular method those alternative methods which require so many pounds of cement to be mixed with so many cubic feet of coarse material and so many cubic feet of sand will seem like a Mrs. Beeton's Cookery Book recipe.

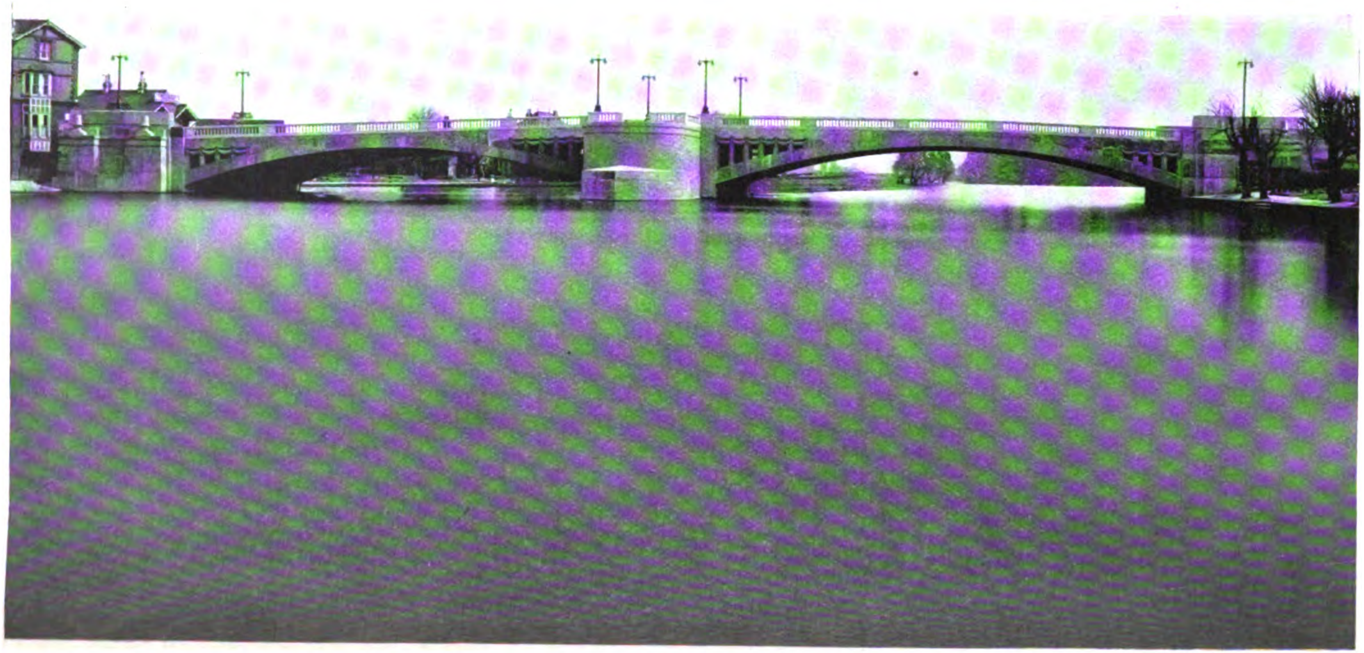
In order to make the suggested rule complete, it should be stated that for reinforced concrete work the volume of sand should be at least sufficient to fill the voids in the coarse material. Generally this will mean that the volume of sand should be at least 50 per cent. of the volume of the coarse materials.

Finally it might be useful to add a simple rule for converting a specification giving the second method into a specification giving the fifth method. Let N represent any given number. When concrete is specified as containing N volumes of aggregate per unit volume of cement, then for most practical purposes that mixture may be described as containing $2N$ cubic feet of aggregate per bag of cement. For example, a four-to-one concrete will contain about 8 cu. ft. of aggregate per bag of cement.

This is the commonest mixture used for reinforced concrete work, but experience has shown that it can only be regarded as rust resistant when the aggregate has been graded in order to reduce the amount of voids. If the aggregate has not been so graded then it may be desirable to reduce the volume of aggregate per bag of cement. Of course, in mass concrete work for foundations these considerations will not apply, and the rate may be increased to 16 cu. ft. of aggregate per bag of cement.

With regard to the question of selling aggregate by weight instead of by volume, it may be urged that weight is constant but volume will depend upon the degree of consolidation. On the other hand, aggregate usually contains a variable amount of water, and differences of water contents will affect the total weight.

Suppose a builder ordered ten tons of gravel which had been dredged from an inundated pit on a rainy day. He might hope to receive ten tons of gravel, and not ten tons of gravel and water. But he would hope in vain !



Caversham Bridge, Reading. (*See p.* 477.)

New Concrete Bridge at Caversham.

The latest reinforced concrete bridge to be built across the Thames, connecting Reading and Caversham, was completed early in May, and formally opened by the Mayor of Reading, while on June 25 the commemoration tablets on the south pylons were unveiled by H.R.H. the Prince of Wales.

This structure replaces a steel bridge built in 1869, and which had become unsuitable for modern traffic. Powers for the erection of a new bridge were obtained in 1913, but it was not until 1924 that work was commenced.

As will be seen from our illustrations, there are rising approach roads, contained between reinforced concrete retaining walls, on the south, or Reading side of the river, and between one such wall and existing buildings on the Caversham side, with massive abutments and pylons in concrete on the two banks of the river. The bridge has two arches having an angle of skew of 78 degrees and clear spans of 126 ft. 4½ in., and 106 ft. 4½ in. on the Reading and Caversham sides respectively, separated by a large abutment and island structure 34 ft. 9 in. broad and 61 ft. 6 in. measured transversely to the bridge. The total length of the whole of the structural work is 457 ft. 6 in. The width of the bridge between parapets is 56 ft., or 59 ft. 1 in. overall, providing a carriageway of 32 ft. and two footpaths of 12 ft. each.

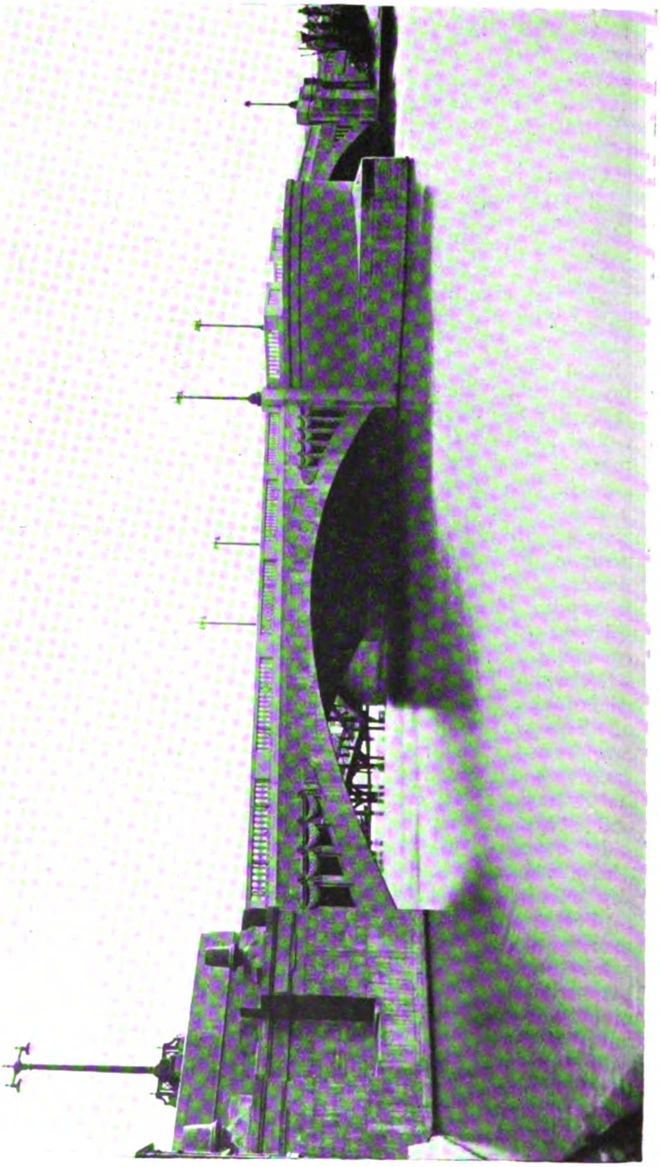
The island structure separating the spans roughly covers a natural island which has been encircled and trued up in shape by reinforced concrete piles and sheet piles, surmounted by reinforced concrete walls carried up to the bridge level and decked over and paved. This structure projects up and downstream on each side of the bridge in the form of promenade bays, semicircular at their outer ends and stepped slightly downwards to afford good lines of sight from all points on to the river.

The design aims at bringing out the character of the principal material employed, concrete, the heavy effect of concrete being retained in the abutments but relieved and broken by set-backs or batters in order to produce form and symmetry of line. The arches are treated in the same manner, and the setting back is a detail persisting through the whole design. Further relief is given by moulded concrete enrichments in the form of swags, ribbons, terminals, etc., along the beams carrying the parapets and at the heads of the reinforced concrete spandrel columns which support the decking.

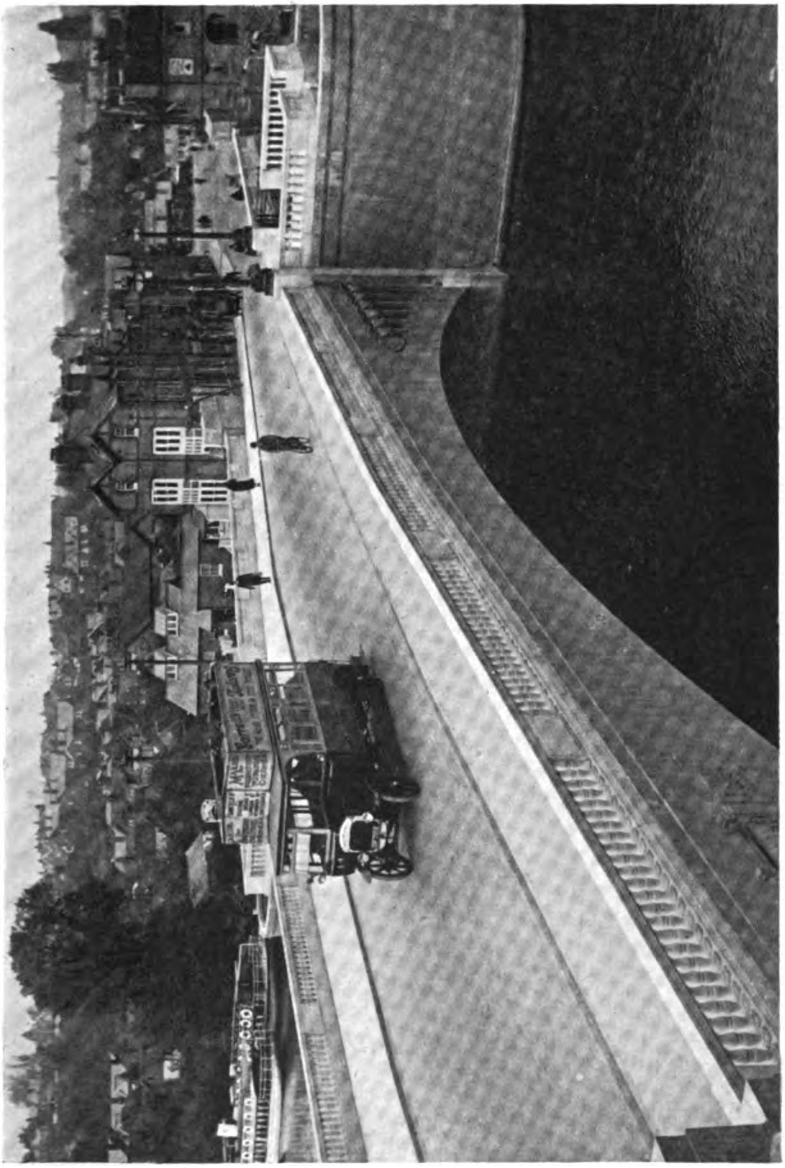
In view of the conditions it was possible to work to a gradient of about 1 in 30 on the Reading side up to a point 57 ft. from the springing of the first arch; this is followed by a practically level stretch of 104 ft., which terminates at the northern end of the central abutment, from which point the road drops with a fall of 1 in 24 to the Caversham side.

Work was first commenced on the north abutment, followed by the centre and south abutments. As the arches are rather flat the thrusts exerted are correspondingly large, and in order to avoid eccentricity of loading, and hence unduly heavy loading of the ground, the sizes and shapes of the mass concrete abutments are such that the resultants of the lines of thrust combined with the dead weight of the abutments and superincumbent filling pass approximately centrally through them. These considerations necessitated the provision of very large and heavy abutments. Again to equalise the pressure on the ground, and at the same time increase the resistance to sliding, the undersides of the abutments are slightly inclined upwards in a landward direction. The maximum thrust exerted by the largest arch is nearly 3,500 tons.

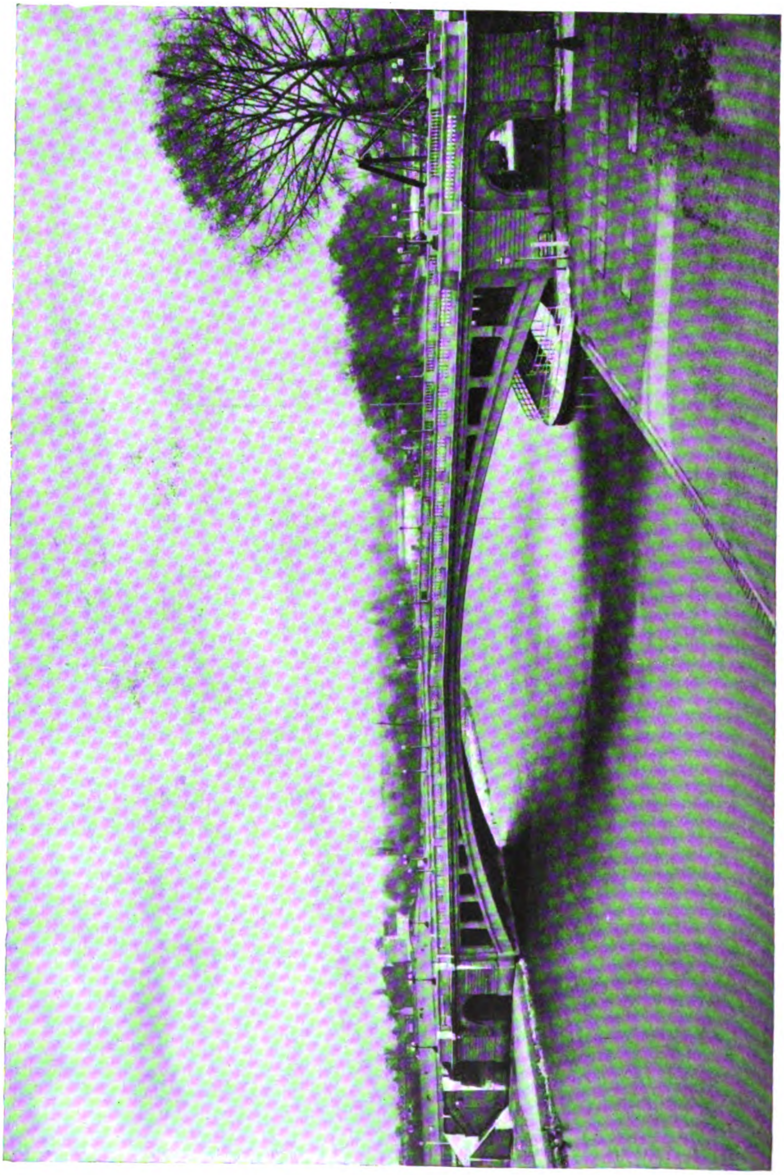
The dimensions of the three abutments are as follows:—North: 57 ft. 6 in. in the direction of the bridge axis, by a width varying from 64 ft. to 54 ft., by 25 ft. 6 in. deep. Central: 44 ft. 9 in. long by 61 ft. 6 in. wide at the base; 26 ft. 9 in. deep; the upper portion slopes inwards to a length of 34 ft. 9 in. in the direction of the axis of the bridge, thus effecting an economy in concrete. South: like the north is approximately 57 ft. 6 in. long in the direction of the axis of the bridge by 64 ft. wide by 26 ft. 6 in. deep. Each of the abutments was constructed inside a box dam of steel sheet piling, the piles varying in length from 30 ft. to 20 ft. The



Caversham Bridge: Upstream Face.



Caversham Bridge.



Reading Bridge (opened 1923).

excavation taken from the three abutments amounted to about 12,000 tons, and the concrete placed in them, 11,200 tons.

The reinforcement of the superstructure, retaining and other walls, arches, and columns is securely anchored into these great masses. At the springing line of the arches large ferro-concrete distributing beams are recessed into the mass-concrete, thus ensuring a complete distribution of the thrusts from the six ribs over the whole mass of the concrete.

The arches are parabolic, their dimensions being as follows:—

	Dimensions of Arch Ribs.					
	South Span.			North Span.		
	Width.	Depth at Springing.	Depth at Crown.	Width.	Depth at Springing.	Depth at Crown.
	in.	in.	in.	in.	in.	in.
Ribs under Roadway .	60	45	29	54	45	29
Ribs under Kerbs . .	54	45	29	48	45	29
External Ribs	27	45	40	24	45	38

Spandrel columns to support the decking spring from the arches until the arches approach the decking, where short lengths of spandrel walls are introduced. The internal columns measure 10 in. by 20 in. The internal walls are 10 in. thick. The external columns are larger for architectural reasons, and measure 18 in. by 27 in. for the south span and 18 in. by 24 in. for the north span. The external walls are 27 in. and 24 in. thick in the south and north spans respectively.

The internal columns support longitudinal ferro-concrete beams 10 in. wide by 20 in. deep below the reinforced concrete decking, and the external columns support longitudinal beams of the same width as the external ribs. The longitudinal main beams support 7 in. by 16 in. secondary transverse beams at 4 ft. centres, the whole system carrying a reinforced concrete decking 6½ in. thick. For a length of 54 ft. over the crown of the south arch and 42 ft. over the crown of the north arch the beamed decking is displaced by a solid decking 12 in. thick spanning from rib to rib.

Expansion joints are provided against the central abutment to afford each large span independent facility for movement.

The walls of the promenade bays practically encircle the old island, and are founded on reinforced concrete sheet piling 7 in. by 18 in., and king piles of 14 in. by 14 in. section, enclosing semicircular bays protruding 33 ft. 6 in. from the line of the parapets by 26 ft. 3 in. wide. These walls are from 6 in. to 8½ in. thick, and are roofed over at bridge deck level by reinforced concrete decking 5½ in. thick carried upon reinforced concrete beams of varying scantlings. The outer, or semicircular, portion of each bay is stepped down 3 ft. 6 in. The parapet walls of these lower bays are of reinforced concrete, while the parapets of the square portions and of the bridge are of granite. A cutwater is formed at the base of the upstream bay, but on the downstream side this is unnecessary and the semicircular form is carried right down to the foundations. A reinforced concrete cantilevered stairway is carried down the north face of the east promenade bay to afford access to an adjacent island.

The north-east, south-east, and south-west retaining walls flanking the north and south approaches have lengths of 58 ft., 63 ft., and 79 ft. respectively, and are all of similar design—thin curtain walls with counterforts and flat foundation slabs carried upon 12 in. by 12 in. reinforced concrete piles (37 ft. 6 in. long on the south side and 15 ft. long on the north side) at 9 ft. centres.

Messrs. L. G. Mouchel and Partners, Ltd., acted as engineers for the work, in collaboration with Mr. A. S. Parsons, M.Inst.C.E., Borough Engineer of Reading. The whole of the reinforced concrete was designed on the Mouchel-Hennebique system by Messrs. Mouchel. The contractors were Messrs. Holloway Bros. (London), Ltd., whose tender price amounted to £63,162.

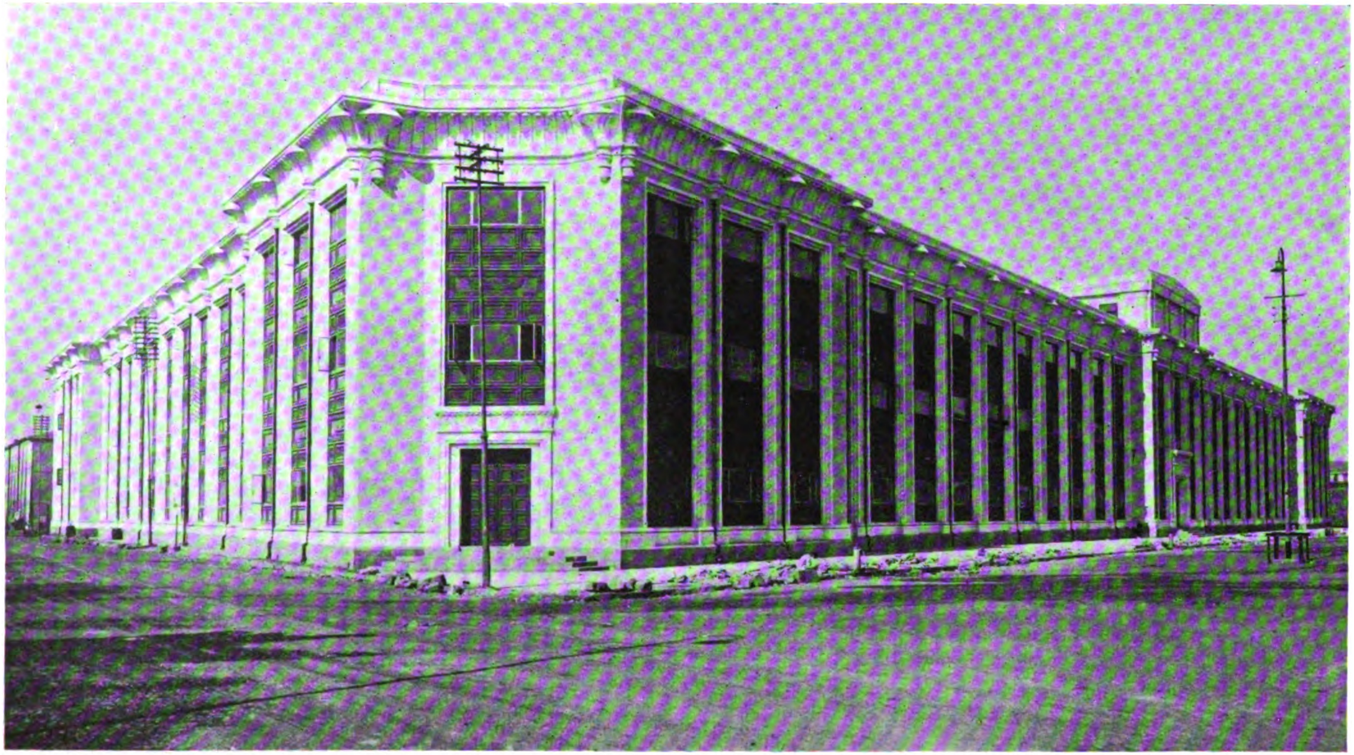


Fig. 1.—Cotton Exchange Building, Bombay. (*See p.* 483.)

Reinforced Concrete in India.

The Cotton Exchange Building.

By R. P. MEARS, M.Inst.C.E.

FIGS. 1 and 2 are views of the finished Cotton Exchange Building as lately constructed for the East India Cotton Association in Bombay by Messrs. J. C. Gammon, Ltd., reinforced concrete engineers and contractors, and Messrs. Rawji Sojpal & Co., contractors, under the general direction of the architects, Messrs. Gregson, Batley & King, of Bombay.

This large building, representing an expenditure of about £150,000, is constructed in reinforced concrete frame with self-supporting exterior walls, as is well shown in *Fig.* 3, which illustrates part of the building during construction. The ground floor covers 45,000 sq. ft. All details of reinforced concrete design were prepared by Messrs. J. C. Gammon, Ltd. The earlier designs were submitted to the scrutiny of Mr. M. G. Cervello, who acted as the client's consultant for reinforced concrete.

The main architectural feature consists of a cornice gutter constructed entirely in reinforced concrete filled against prepared plaster-of-Paris moulds.

Owing to the damp and uncertain nature of the soil foundations were taken deep, and the ground floor constructed self-supporting in slabs and beams of reinforced concrete as is the case with the upper floors. The roof is built up in hollow block slabs of 15-ft. spans, and subsequently top-graded and waterproofed. Hollow floors and roofs, though the usual practice in London for many years past, have only recently become common in Bombay, as suitable hollow bricks are not made locally; for these floors specially moulded hollow concrete blocks had to be made. Both in this building and others recently constructed in India, very great advantages as regards sound-proofness and coolness are obtained by this method of construction. Instances have been recorded of temperatures taken in the heat of the day showing 10 deg. (Fahr.) lower temperature under a hollow roof than under any ordinary roof. The advantages of clear and unobstructed ceilings of large span are also obvious. With good organisation the cost can be brought down to only two or three pence per square foot above the price of the ordinary small-span solid slab.

The staircases are constructed entirely in reinforced concrete. Specially manufactured nosings protect the stair edges, and chequer tiles in concrete form the treads, and the risers are cement rendered.

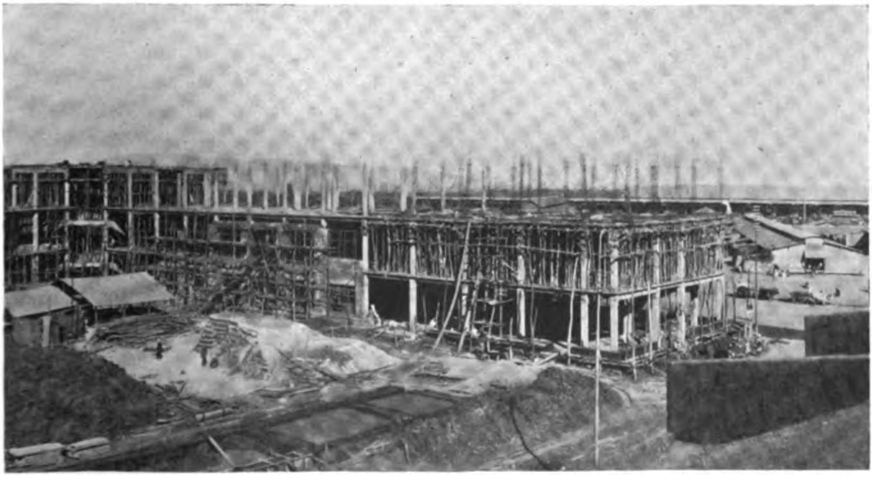


Fig. 3.—View during Construction.

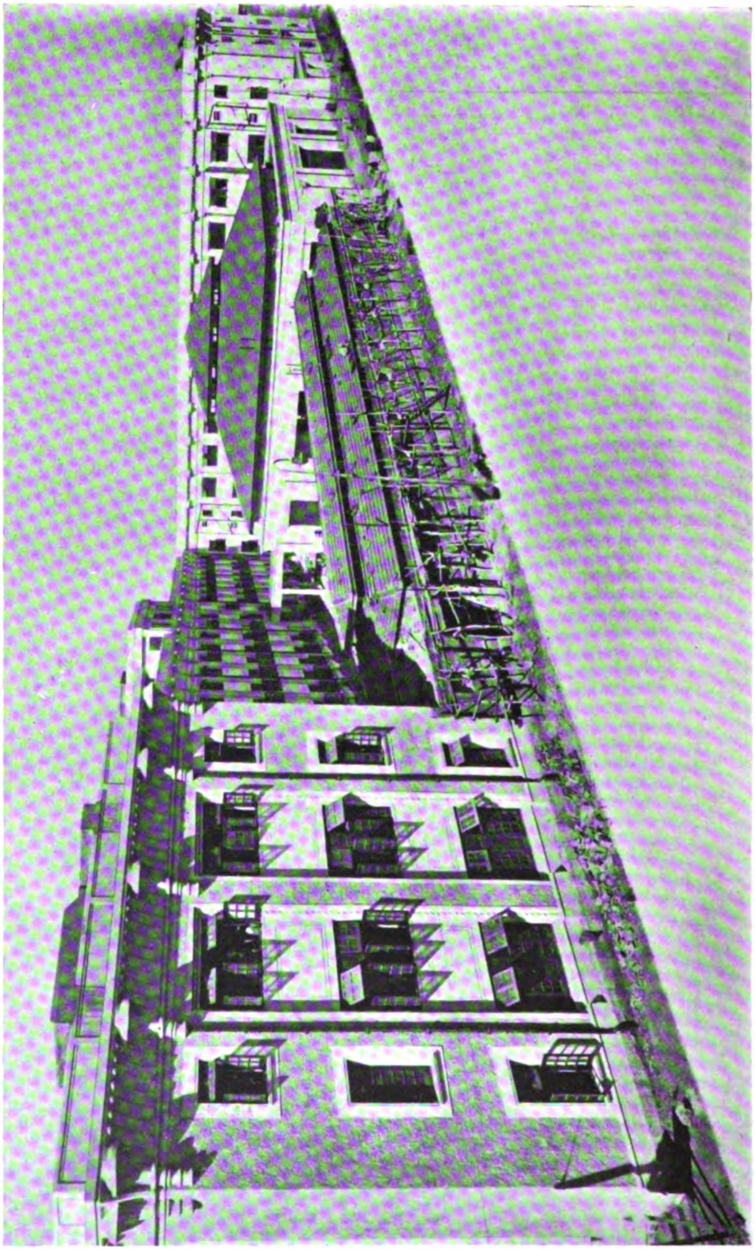


Fig. 2.—Cotton Exchange Building, Bombay.

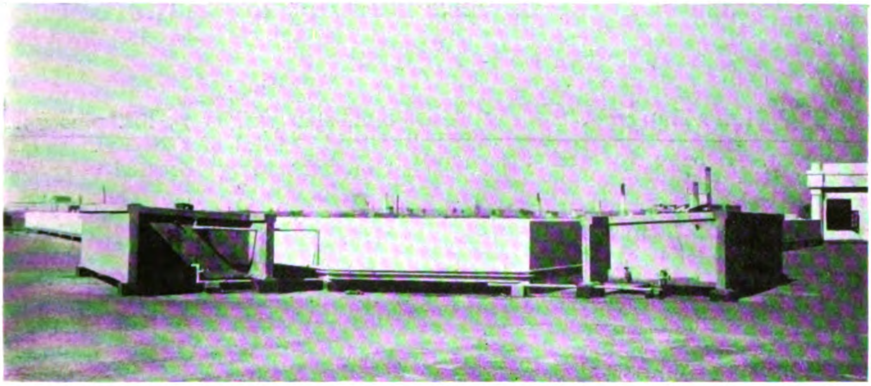


Fig. 4.—Roof Storage Tanks.

Fig. 4 shows the roof storage tanks which are also entirely of reinforced concrete. Below ground level in the yard is a large reinforced concrete water-storage tank and three similarly constructed septic tanks. There are five roof-storage tanks, each of two compartments—they were all constructed and brought into use within one month of the date of receipt of the order.

The Cotton Exchange building is situated in the recently constructed cotton area in Bombay, built entirely on a reclamation under the Bombay Port Trust.

Reinforced Concrete Lining for Liffey Tunnel.

THE Streets Section of the Dublin Corporation, in recommending the acceptance of the tender of Messrs. Sir Robert McAlpine & Sons (Ireland), Ltd., at £28,665, for the construction of a tunnel through the rock under the river Liffey, reported that it was proposed by the firm that a special form of reinforced lining, the patent of which the Company had acquired from the inventor, Herr Wolfscholtz, formerly the consulting engineer of the Simplon Tunnel, be used, but intimated that they were prepared to construct the tunnel at their quoted price, using either the Wolfscholtz method of lining, the McAlpine patent pre-cast reinforced concrete lining, or cast-iron segments. The report continues : " As the Wolfscholtz method has not yet been adopted in Great Britain or Ireland, it was thought advisable, before recommending acceptance of the tender, that the engineers who would have the responsibility of carrying out the contract should have an opportunity of inspecting the proposed method of construction. A visit was paid to Frankfort-on-Main, where the Wolfscholtz system of lining was inspected, and as a result of the inspection, and on the advice of the Acting City Engineer and Mr. Henry Nicholls, B.A., the adoption of the Wolfscholtz method of construction, which had only recently been patented, was not recommended. The acceptance of the McAlpine system of reinforced concrete lining for the tunnel was advised."

The firm first proposed that the concrete segments should be composed of 4½ to 1 concrete 3 in. thick, but after consultation between one of the directors and the Acting City Engineer it was agreed to make the segments of 4 to 1 concrete 4 in. thick, without extra cost.

Questions and Answers relating to Reinforced Concrete.

Stone Bunkers.

QUESTION.—I have to design some stone bunkers, 2-in. grade downwards, and shall be much obliged if you will advise me as to the shape, position, etc., of the discharge. The average capacity will be about 300 tons, and the depth inside about 8 or 9 ft. According to Ketchum (" Grain Bins, Elevators, etc."), the area of discharge should be about $\frac{1}{150}$ area of bunker; do you agree with that?

To what extent will the discharge for a stone bunker differ from a coal or grain bunker? Is it only a question of the angle of repose plus the friction angle?

W. G. M.

ANSWER.—The area of discharge of a bunker depends only on the speed at which the bunker is to be discharged, and we do not think there is any definite relationship that need hold between the area of discharge and the area of a bunker. The discharge for a stone bunker differs from coal or grain chiefly in variation in the angle of repose and friction angle. It can easily happen that the stone may " dome " over the discharge opening and discharge cease altogether. Some provision for agitation in such circumstances is therefore often desirable.

Design of Formwork.

QUESTION.—I would be much obliged if you would give the working out in detail of formula 15 in Design of Formwork for Reinforced Concrete Construction, by A. E. Wynn, in your issue for November 1924. Taking, for example, 1-in. sheathing as for floor slabs in Table 1 (December 1924), also for 1-in. column sheathing instead of formula 3 as used in Table 3, taking height of column as 10 ft. and w as 125,

$$\text{Formula 15 } L = 10{\cdot}25\sqrt[4]{\frac{d^3}{w}}$$

$$D = \tfrac{1}{8}.$$

—T. P.

ANSWER.—To show the application of formula 15 to the design of floor sheathing, we will find the maximum span of 1-in. sheathing to carry a 6-in. slab.

6-in. slab weighs 75 lbs. plus 75 lbs. live load = total of 150 = w.

1-in. sheathing dressed = 13/16 = 0·8125 in.

$$\text{Max. span 1-in.} = 10{\cdot}25\sqrt[4]{\frac{0{\cdot}8125^3}{150}}$$

= 2·5 ft. = 30 in. as is given in Table 3.

To apply the same formula to the design of column sheathing we will take a column 10 ft. high and find the maximum span of the sheathing for a deflection of $\frac{1}{8}$ in. at this depth.

Since $w = 125$, $wh = 125 \times 10 = 1250$.

As before, 1-in sheathing = 0·8125 in.

$$\text{max. span 1} = 10{\cdot}25\sqrt[4]{\frac{0{\cdot}8125^3}{1250}}$$

= 1·475 ft. = 17·7 in.

This is greater than is given in Table 3, since, as is explained, the span of column sheathing is governed by bending, not deflection.—A. E. W.

Strength of Slabs.

QUESTION.—In September of 1925 you were good enough to answer my queries *re* the strength of concrete, and I quote a portion of your reply: " In the case of non-reinforced slabs, ignoring the arching action of the concrete the safe resisting moment in all cases is given by $\frac{fbd^2}{6}$, where f is the safe stress in the concrete in tension. This may be taken as 60 for 1 : 2 : 4 concrete; 45 for 1 : 3 : 6; and 30 for 1 : 4 : 8." This apparently gives for, say, 1 : 2 : 4 concrete, $\frac{60}{6}bd^2$, equalling $10bd^2$. This seems to me to be remarkably small. Could you please tell me if this is as I have read it, or is it $\frac{f}{6} = 60$? I should also be pleased if you would give me the safe shear values of concrete of 1 : 2 : 4, 1 : 3 : 6, and 1 : 4 : 8 mixtures.—H. P.

ANSWER.—The reply to the first question is that $10bd^2$ is correct. In reply to the second question, the safe shear values for the different mixes of concrete mentioned are as follows: 1 : 2 : 4, 60 lbs. per sq. inch; 1 : 3 : 6, 45 lbs. per sq. inch; 1 : 4 : 8, 30 lbs. per sq. inch.

Controlling the Manufacture of Concrete to obtain Uniformity of Strength.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

(*Continued.*)

Job Equipment for Designing Mixtures.

It may seem that a lot of laboratory work is required to design a mixture, taking all the various factors into account, but actually it is comparatively simple and a complete design can be made in thirty minutes. What is needed more than anything else is a thorough understanding of the influence of each varying factor, and knowing how a change in one or more factors will influence the workability and strength of the concrete. Job experiments can be carried out with any degree of accuracy and cost of equipment desired.

However, it has been found that sufficiently accurate and reliable results can be obtained with the following simple equipment standardised for field use. (Field Testing Set No. 2, W. S. Tyler Co., Cleveland, Ohio.)

1 set of sieves Nos. 50, 16, 4, ⅜ in., and ¾ in.
1 measuring can, 2⅞ in. diameter and 10 in. high.
1 measuring can, 5⅜ in. diameter and 11 in. high.
1 slump cone, 4 in. top diameter, 8 in. bottom diameter, and 12 in. high.
20 6 in. by 12 in. cylinder moulds.
1 ⅝ in. pointed round steel rod.
2 pieces of light canvas duck, 36 in. square.
1 12 in. mason's trowel with blunt end.
1 12 in. rule graduated into tenths of an inch.
Cross-section paper.

Only alternate size sieves are used, the points on the sieve analysis curve for the other sieves being found by interpolation. Sieves are semi-cylindrical and fit together in the large metal container. Proportions are found by volume instead of by weight, eliminating scales and measuring the volumes in the cans by rule. The cylinder moulds are for taking specimens for compression tests; the canvas is used for sampling and mixing the aggregate.

Design of a Mixture by the Fineness Modulus Method.

We will assume that it is desired to obtain a concrete that will have a strength of 2,000 lbs. per sq. in. at the end of 28 days, and that it is for the construction of a reinforced concrete factory. The aggregate available is sand and washed gravel, clean and structurally sound. It is required to know in what proportions to mix the ingredients to give the required strength with the most economy. Field operations are to be strictly controlled.

The consistency must be such that the concrete will flow freely around the reinforcing steel, so that a slump of 6 in. is required. From *Fig.* 1, using *Curve A*—since field operations are to be controlled—for a strength of 2,000 lbs. (equivalent to 1,500 lbs. on *Curve B*) we need a water-cement ratio of 1·00, or for every cubic foot of cement we need a cubic foot of water, or 6·24 imperial gallons.

Take samples of the aggregates, about 10 lbs. of sand and 20 lbs. of gravel,

Sieve Size	Sand % Retd	Gravel % Retd.
100	100	100
50	94	100
30	52	100
16	29·5	100
8	15	100
4	3	95
3/8"	0	67
3/4"	0	28
1½"	0	0
	100)293·5 M_f = 2·93	100)690 M_c = 6·90

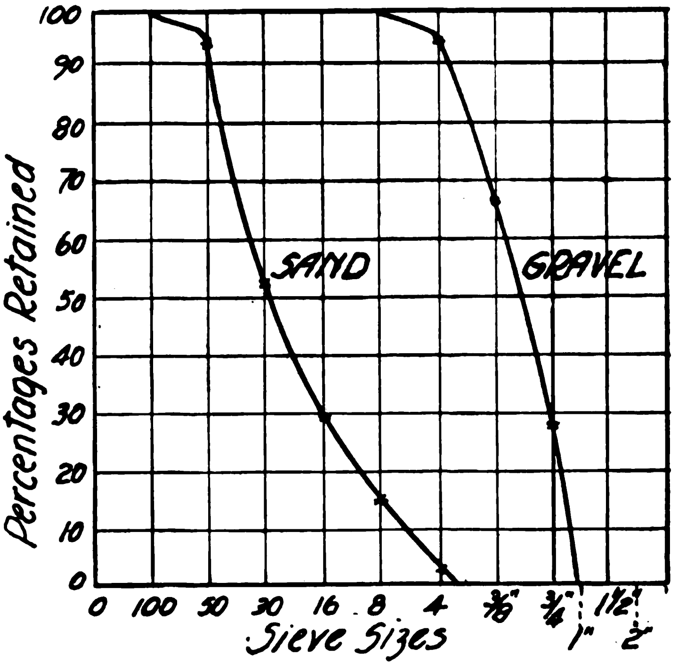


Fig. 5.—Calculation of Fineness Modulus.

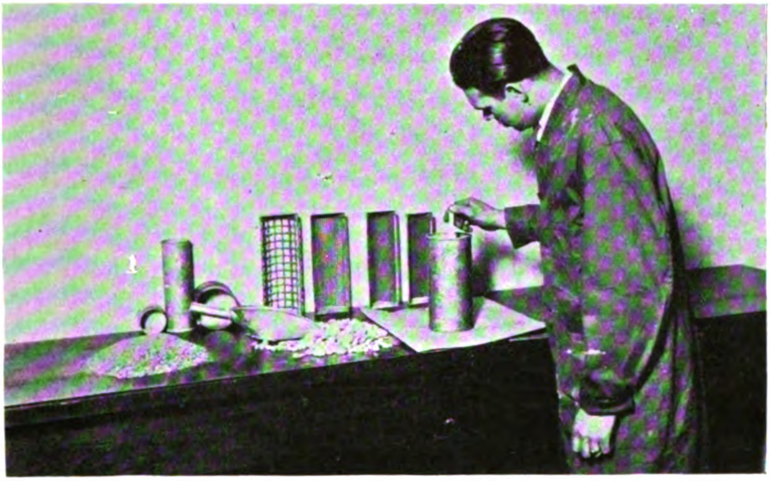


Fig. 4.—**Measuring Volumes for obtaining "Fineness Modulus" by Field Testing Set.**

and thoroughly dry them. (It is important that the samples are truly representative of what will be supplied.) Spread the sand out on the canvas in a circle about 3 in. deep and mix thoroughly; quarter the sample, discarding opposite quarters; re-mix and quarter again, until a sample of required size is obtained. Sieve through each sieve in turn on to a sheet of paper. Measure the volumes retained on each sieve in the smaller can, by measuring down from the top and deducting from 10 ins. (*Fig.* 4).

				per cent.
Retained on	¾ in. sieve	0 ins.		
,, ,,	⅜ ,, ,,	0 ,,		
,, ,,	No. 4 ,,	0·25 ,,	coarser than No. 4	2·94
,, ,,	,, 16 ,,	2·25 ,,	,, ,, ,, 16	29·4
,, ,,	,, 50 ,,	5·5 ,,	,, ,, ,, 50	94·1
Passing through	,, 50 ,,	0·5 ,,	,, ,, ,, 100	100
Total		8·5 in.		

Treat the sample of gravel in the same manner.

				per cent.
Retained on	¾ in. sieve	2·5 in.,	coarser than ¾ in.	27·8
,, ,,	⅜ ,, ,,	3·5 ,,	,, ,, ⅜ ,,	66·7
,, ,,	No. 4 ,,	2·5 ,,	,, ,, No. 4	94·4
,, ,,	,, 8 ,,	0·5 ,,	,, ,, ,, 8	100·0
Total		9·0 in.		

With the sieve sizes as abscissæ, using a full set, and with the percentages coarser than each sieve as ordinates, plot the points found above and draw smooth curves through them (*Fig.* 5). From the curves read the percentages coarser than each size sieve, and tabulate them as shown. Add them together and divide by 100, giving the fineness moduli of the sand and gravel.

The range in size will be 0 to No. 4 for the sand and No. 4 to 1 in. for the gravel. (Note that the 1 in. and 2 in. sieves are used for grading the size only, and not in finding the modulus.)

From *Fig.* 3 the intersection of the 1,500 lb. curve—equivalent to 2,000 lbs. with control—with the 1 in. maximum size curve on the 6 in. to 7 in. slump chart, projected down, gives $5{\cdot}3 = M$, for the fineness modulus of the mixture. The same point projected horizontally gives 1 : 5·2 for the real mix. (Note that on *Fig.* 2 the maximum possible fineness modulus for the amount of cement used would be between 5·4 and 5·25.

Find proportion of sand to total volume of sand and gravel,

$$r = \frac{M_c - M}{M_c - M_f} = \frac{6{\cdot}9 - 5{\cdot}3}{6{\cdot}9 - 2{\cdot}93} = 40{\cdot}3 \text{ per cent.}$$

The next operation is to find the amount of shrinking in volume when 40 per cent. of sand and 60 per cent. of gravel are mixed together. Mix together 4 in. of *dry rodded* sand and 6 in. of *dry rodded* gravel. If they now measure 8·5 in. the shrinkage factor is $\frac{8{\cdot}5}{10} = 0{\cdot}85$. Therefore for a real mix containing 5·2 parts of mixed aggregate we shall need $\frac{5{\cdot}2}{0{\cdot}85} = 6{\cdot}12$ parts of sand and gravel measured separately.

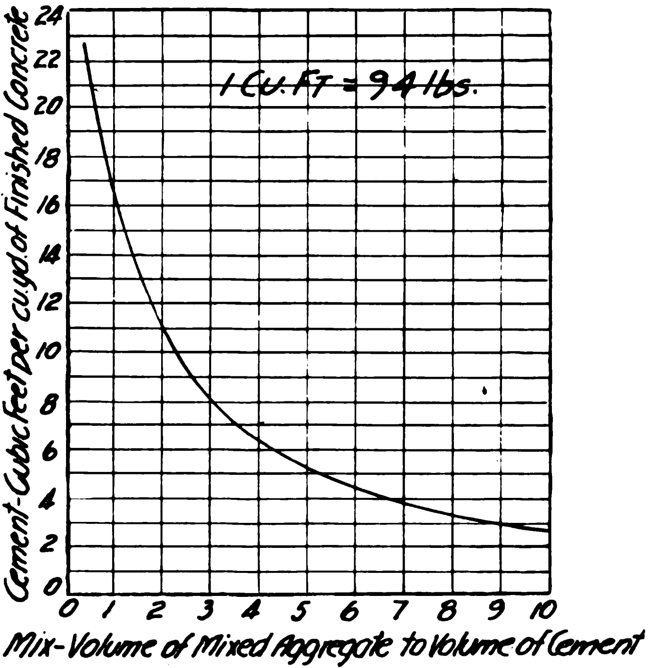


Fig. 6. CEMENT PER CU. YD. OF CONCRETE

We shall require therefore :

$$6{\cdot}12 \times 0{\cdot}40 = 2{\cdot}45 \text{ parts of sand, and}$$
$$6{\cdot}12 \times 0{\cdot}60 = 3{\cdot}67 \text{ parts of gravel,}$$

so that the nominal mix is 1 : 2·45 : 3·67 for *dry rodded* material. This proportion has to be corrected for job conditions of damp material.

To find the percentage of bulking, fill the 10 in. can with loose damp sand, as it is on the job ; dry the sand, and place it back in the can in three layers, rodding each layer. If the depth is now 8¾ in. the bulking is $\frac{1{\cdot}25}{8{\cdot}75} = 14{\cdot}3$ per cent. ; therefore for 2·45 cu. ft. of dry sand we need $2{\cdot}45 \times 1{\cdot}143 = 2{\cdot}8$ cu. ft. of damp sand. Repeating the experiment with the gravel, if the depth of the dry rodded material is 9·75 in. the bulking is $\frac{0{\cdot}25}{9{\cdot}75} = 2{\cdot}56$ per cent. and we shall need $3{\cdot}67 \times 1{\cdot}02 = 3{\cdot}75$ cu. ft. of damp gravel. The field mix is then 1 : 2·8 : 3·75.

To find the quantities required per cu. yd., from *Fig.* 6, for a real mix of 1 : 5·2, 5 cu. ft. (or 470 lbs. of cement) are required, so that

quantity of sand per cu. yd. $= 5{\cdot}0 \times 2{\cdot}8\ /27 = 0{\cdot}52$ cu. yd. and
,, ,, gravel ,, ,, ,, $= 5{\cdot}0 \times 3{\cdot}75/27 = 0{\cdot}70$,, ,,

The field quantities for one cu. yd. of concrete will be 470 lbs. of cement, 0·52 cu. yd. of sand, and 0·70 cu. yd. of gravel.

There remains only the amount of mixing water required, and this is really the most important. We have seen that 6·24 gallons are required for each cu. ft. of cement, but from this has to be deducted the water already in the sand and gravel.

For sand it can be assumed that for percentages of bulking of 15, 20, 25, and 30 the water content will be 2, 3, 4, and 5 per cent. by weight respectively. Coarse aggregate will contain 1 to 2 per cent. by weight of moisture. The weight of sand can be assumed at 90 lbs. per cu. ft., and of gravel 100 lbs., or it can be determined exactly.

Since we have found the bulking in the sand to be 14·3 per cent. we will assume there is 2 per cent. of moisture present, and since this is low we will assume 1 per cent. for the gravel.

Then water to be deducted for sand per cu. yd. $= \frac{0{\cdot}52 \times 27 \times 90 \times 0{\cdot}02}{10} = 2{\cdot}5$

,, ,, ,, ,, ,, gravel ,, ,, ,, $= \frac{0{\cdot}70 \times 27 \times 100 \times 0{\cdot}01}{10} = 2{\cdot}0$

Total to be deducted = 4·5 gallons.

No allowance need be made for absorption, as the aggregate is already damp.

Amount of water required per cu. yd. of concrete is $(5 \times 6{\cdot}24) - 4{\cdot}5 =$ say, 26·5 gallons. As the slump is to be 6 in., this amount of water can be increased or decreased slightly if necessary to give this slump (the total amount must not exceed 31·2 gallons).

If desired the exact water content can be determined by weighing a cu. ft. of aggregate, loose and damp, drying it and weighing again ; the difference in weights will be the amount of water contained.

The design of a concrete mixture with the available aggregate, to give a strength of 2,000 lbs. in 28 days with a slump of 6 in. is now complete. Note that, without rigid field control, the minimum strength that would be expected is 1,500 lbs. In some parts of the building, as, for instance, in footings and perhaps walls, a slump of 3 in. could be used and the mixture designed accordingly with more economy.

Comparison in Economy Between Different Aggregates.

If the sand used in the above instance were the only sand available but it was possible to obtain crushed stone, it would be necessary to know which would be the cheaper to use.

The properties of the stone are, say, $M_c = 7{\cdot}2$; grading ⅜ in. to 1½ in.; shrinkage factor, 0·875 ; bulking negligible. From *Fig.* 3 the fineness modulus of the mixture is 5·7, from which must be deducted 0·25 = 5·45, because crushed stone is used instead of gravel, and the "real mix" is 5·3. Then

$$r = \frac{7{\cdot}2 - 5{\cdot}45}{7{\cdot}2 - 2{\cdot}93} = 41 \text{ per cent.}$$

For a "real mix" of 5·3 we shall need 5·3/0·875 = 6·05 parts of separate aggregates. The "nominal mix" will be : sand, 6·05 × ·41 = 2·48, and stone 6·05 × 0·59 = 3·57. Correcting sand for bulking, the amount of damp sand = 2·48 × 1·14 = 2·83. The "field mix" will thus be 1 : 2·83 : 3·57.

From *Fig.* 6, 5 cu. ft. of cement per cu. yd. are required, so that the amount of sand = 5 × 2·83/27 = 0·52 cu. yd., and the amount of stone = 5 × 3·57/27 = 0·66 cu. yd.

Assume prices of materials delivered on the job are : cement 2*s*. 9*d*. per 100 lbs. ; sand, 16*s*. per cu. yd. ; gravel, 10*s*. 6*d*. per cu. yd. ; and stone, 14*s*. per cu. yd. Then the cost of the gravel concrete would be 28*s*. 7*d*. per cu. yd. and of the stone concrete 30*s*. 6*d*., so that the former would be more economical.

Effect of Arbitrarily Changing the Proportions.

The proportions as designed will give the most economical mixture, that is the greatest yield per cu. ft. of cement for a certain consistency ; other mixtures will have the same strength so long as the water-cement ratio is not changed, but they will be less economical or give a different consistency. By making arbitrary changes in the proportions we can see what the results will be, the strength being unchanged.

Using the same ratio of fine to total aggregate (40 per cent.), if we increase the volume of aggregate without changing the ratio of water and cement the consistency will be drier and the slump less. It will be seen from *Fig.* 3 that for a 3 in. to 4 in. slump the real mix can be 1 : 1·65, or for ½ to 1 in. slump it can be 1 : 1·75, which shows the economy in using drier mixes.

With the same constants, if we reduce the volume of aggregate the slump will be greater, and as seen from the 8 in. to 10 in. chart the real mix will be 1 : 3·5, which is not economical.

If now we use the same volume of aggregate but change the proportion of sand to 30 per cent., this will increase the fineness modulus of the mixture to 5·7, which we know is too high for the amount of cement used or the mixture will be too coarse to work. So in order to use these proportions we have to add more mortar (cement and water in the same proportions) ; this will increase the slump, and on the 8 in. to 10 in. chart it will be seen that for $M = 5{\cdot}7$ the " real mix " will be 1 : 4, and this will still give a harsh mixture and not be economical.

If we change the proportion of sand to 50 per cent., the fineness modulus of the mixture will be 5·0, and in order to have a 6 in. slump the " real mix " must be 1 : 4·8, or again we have more cement.

Designing a Concrete Mixture by the " Trial Method."

We know that strength depends only on the water-cement ratio, and that for economy as much aggregate as possible should be added to give a workable mix of the desired consistency. The " fineness modulus " method is an easy way of proportioning the aggregate, but if it seems too technical for some the same results can be obtained approximately by trial. It is simply a question of finding the densest mixture per cubic foot.

Take a cubic foot box or any container of known capacity and fill it with a mixture of dry fine and coarse aggregate in different proportions, say, 30, 35, 40 and 45 per cent. fine to total volume. The proportions that will give the heaviest mixture will be approximately the most economical, giving the greatest yield of concrete. Corrections for bulking can be made as previously described.

The water-cement ratio is fixed for the strength required. Mix up a batch of cement and water and add all the aggregate possible (in the proportions found economical) until the required consistency is obtained, which can be checked by the slump test. The proportions of fine to coarse aggregate and the proportions of both to the cement are thus determined. Corrections to the amount of water required for water content in the aggregate can be governed by the slump.

This method is being used successfully, and as it requires no technical knowledge it is particularly suitable for contractors to use when there is no engineer on the job.

Tests.

The slump test (*Fig.* 7) is a check on the consistency and should be made daily or whenever there appears to be a change in the consistency. It also affords a means of regulating the quantity of water for changes in the moisture content of the aggregate. On important jobs specimens for compression tests should be taken at regular intervals, say, three to five per week as the work progresses. The results of the compression tests will be a check on the design of the mixture, and may often show that further economies can be made. On all jobs of moderate size a few test specimens should be made at the start from trial batches and tested at 7 days to check the strength obtained for a certain water-cement ratio.

The strength may vary a little with different brands of cement, so that the water-cement ratio should be determined for the brand used. The curves of *Fig.* 1 are based on certain cements and conditions of test, and can be taken as reliable for average conditions as they are based on the results of thousands of tests. Cements in other countries may have somewhat different properties, so that the water-cement ratio curve should be found by trial on each important job.

After the mixture has been designed, a batch should be mixed up using a water-cement ratio of say 1·00. From the batch 5 or 6 specimens should be made in the cylinder moulds and tested at 7 days. The strength at 28 days can be calcu-

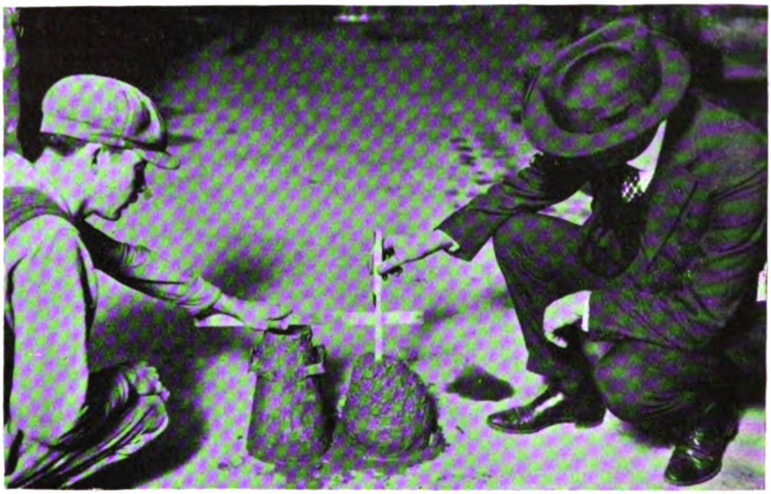


Fig. 7.—Making the Slump Test.

lated closely from the formula $S_{28} = S_7 + 30\sqrt{S_7}$, where S_{28} is the strength at 28 days and S_7 the strength at 7 days.

Referring now to *Fig.* 1, if the strength obtained is plotted for the water-cement ratio of 1·00, the job curve can be drawn in parallel to *Curve A* or *B*, depending on whether the concrete is to be strictly controlled or not. This curve will then be used throughout the job.

Test specimens should be taken from the forms or just before depositing. The moulds should be set on a glass plate and the concrete deposited in 3 in. or 4 in. layers and puddled. The top should be struck off with a trowel, and after 2 to 3 hours covered with a thin layer of neat cement mortar worked to a smooth surface. At the end of 48 hours the specimens should be removed from the moulds and buried in damp sand until required for testing. Test specimens should always be made, cured, and tested in the same manner to give true comparisons of strength.

(*To be concluded.*)

Committee on Dating and Sealing Patents.

THE Board of Trade has appointed a Committee consisting of Mr. J. Whitehead, K.C. (Chairman), Mr. H. A. Gill, M.A., Mr. A. J. Martin, O.B.E., Major-General Sir Philip Nash, K.C.M.G., C.B., and Mr. J. Swinburne, M.Inst.C.E., F.R.S., to inquire into and report whether any, and if so what, change is desirable in the practice of the United Kingdom of (*a*) dating and sealing patents applied for under Section 91 of the Patents Acts, 1907 and 1919, as of the date of the application in the foreign state; and (*b*) dating and sealing other patents as of the date of application, as provided by Section 13 of the Acts. The Secretary to the Committee is Mr. B. G. Crewe, The Patent Office, 25, Southampton Buildings, London, W.C.2, to whom all communications relating to the work of the Committee should be addressed.

The Cement-Water Ratio Theory in Practice.

IN the issue containing Mr. A. E. Wynn's article on modern American methods of specifying concrete strengths it is of interest to be able to record an important reinforced concrete building in which these principles were used. This structure is the new office and laboratory building in Chicago of the Portland Cement Association, in which the strength of the concrete was controlled without the use of special equipment or testing organisation, solely by means of a specification based upon the control of the water. This specification fixed only the proportion of water to cement. The aggregate proportions were left entirely to the judgment of the contractor, with the limitation that plastic and workable mixes be produced. Other than standard paragraphs dealing with quality of materials, etc., the entire matter of proportioning and strength appeared in the specifications in the following paragraphs.

" *Water-Cement Ratio.*—Concrete for structural members shall be proportioned to give the necessary workability without exceeding the following ratios of water to cement :

	Water per sack (94 lb.) of cement.
Where concrete of strength of 2900 lbs. per sq. in. is called for	6·0 U.S. gal.
Where concrete of strength of 2000 lbs. per sq. in. is called for	7·5 U.S. gal.

" These water-cement ratios are the maximum permissible. The mixes shall be proportioned for somewhat lower ratios, so that with the normal fluctuations which may be expected from batch to batch these ratios will not be exceeded. Water or moisture contained in the aggregate must be included in computing the water-cement ratios. Water absorbed by the aggregate in a period of 30 minutes may be deducted in computing the water-cement ratio. The water-cement ratios specified shall not be changed except by the architect. In the event that the architect finds it necessary to change the water-cement ratios from those specified, adjustment, covering amount of cement and aggregates affected, will be made as an extra or a credit under the provisions of the contract.

" *Concrete Proportions and Consistency.*—The proportions of aggregate to cement for concrete of the water-cement ratios specified shall be such as to produce concrete that can be puddled readily into the corners and angles of the form and around the reinforcement without excessive spading and without undue accumulation of water or laitance on the surface. In no case shall concrete be placed which shows a slump exceeding the following limits :

	Max. Slump.
For caissons	4 in.
For heavy walls, slabs and beams .	7 in.
For thin walls and columns . .	9 in.

" The proportion of fine and coarse aggregates shall be such that the ratio of the coarse to the fine shall not be less than 1 nor more than 2, nor shall the amount of coarse material be such as to produce harshness in placing or honeycombing in the structure. When forms are removed, the surface and corners of the members shall be smooth and sound throughout."

This form of specification was prepared by Mr. F. R. McMillan and Mr. Stanton Walker, from whose paper read before the recent annual convention of the American Concrete Institute these particulars are taken.

Questions of economy, as affected by the consistency, proportions, and size and grading of the aggregates, were left to the contractor, in the same way as are questions of plant lay-out procedure. This method has been successfully tried out by a number of engineers, and in this building (designed and supervised by Messrs. Holabird and Roche, architects, Chicago, and constructed by the Turner Construction Company) the specification is stated to have still further proved its worth. It produced concrete stronger than called for, and yet made it possible for the contractor to save money on the work.

The operation of the specification was closely observed and a regular programme of tests was carried out by the Structural Materials Research Laboratory. The compressive strength of the concrete was determined at 3, 7, and 28 days by 6 in. by 12 in. cylinders taken each day from several batches immediately before they were deposited in the forms. Frequent determinations of sieve analyses and of moisture content of the aggregates were made throughout the work. In general

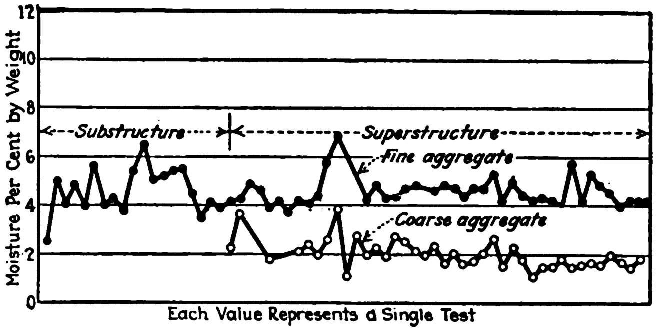


Fig. 1.—Moisture Content in Aggregate.

the tests were made in accordance with the standard methods of the American Society for Testing Materials.

As may be seen in the specifications quoted there were two classes of concrete specified, one to attain a 28-day strength of 2900 lbs. per sq. in. and another that would be at least as strong as 2000 lb. The water-cement ratios governing these strengths, as given in the specifications, were only the maximum permissible. Operating tolerance to cover variations in proportioning was required to be entirely on the lower side, so the actual ratios used were somewhat richer than actually required. It was found to be to the contractor's advantage to keep the fluctuations at the lowest possible limit permitted by the equipment available, as by so doing he was able to secure the specified strengths with a minimum amount of cement per yard of concrete. Under this arrangement the contractor was permitted to use the simplest possible plant, but a greater uniformity in strength might have been possible had more accurate measuring devices been used.

As the specifications on strength and on workability worked out there was no occasion for argument over the consistency or proportions. In placing the concrete in the caissons the tendency was towards the use of consistencies approaching the limit of stiffness. On the superstructure the tendency was towards the other extreme. When it seemed to be desirable to have a more fluid mix, it was obtained by reducing the aggregate proportions, leaving the water and cement quantities in the batch unchanged. The conflicting desire on the part of the contractor always to have plastic workable mixes and yet to keep the cement factor low by the use of the largest possible amount of aggregates resulted in mixes entirely within the range specified and very suitable for the work.

The average mixes and the resultant slumps for the different classes of concrete and portions of the structure are given in the table below.

The contractor was required to measure the materials in such a way that the water-cement ratio could be closely controlled during the progress of the work and easily checked at any time. To simplify control, aggregates had to be purchased

Class of Concrete 28-day Strength lbs. per sq. in.	Average Mix: Damp and Loose	Average Mix: Dry Compact	Average Slump in.
	SUBSTRUCTURE		
2000	1 : 3·0 : 5·4	1 : 2·5 : 4·5	1½
2900	1 : 2·4 : 3·5	1 : 2·0 : 3·25	1¼
	SUPERSTRUCTURE		
2000	1 : 3·0 : 3·9	1 : 2·5 : 3·6	7
2900	1 : 2·0 : 3·0	1 : 1·7 : 2·7	6

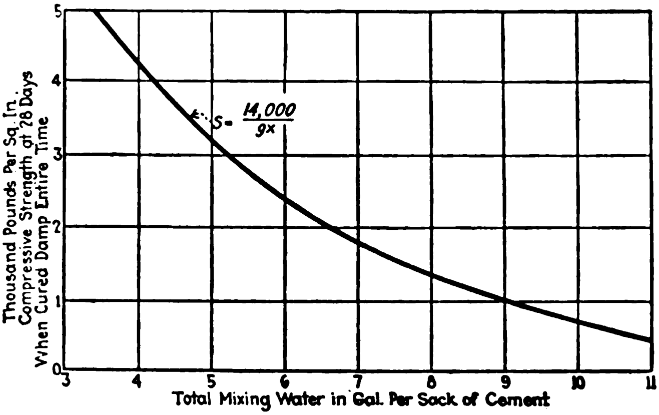


Fig. 2.—Concrete Proportioning Curve for Small Jobs.

Note 1: By " total mixing water " is meant water in the sand and stone plus that added at the mixer. Note 2: Very wet sand will contain from ¾ to 1 gal. per cu. ft. Moderately wet sand will contain about ½ gal. per cu. ft. Moist sand will contain about ¼ gal. per cu. ft. Moist gravel or crushed rock will contain about ¼ gal. per cu. ft. Note 3: The coarser the sand the less water it will carry. Note 4: A sack of cement = 1 cu. ft., or 90 lbs.

from such a source as to ensure uniform grading and quality during each day's operation. Aggregates were delivered by truck and stored on the street in small quantities; good delivery service made small stock piles possible. The aggregates were measured in wheel-barrows on the caisson work and in buggies on the superstructure construction. Frequent moisture determinations were made on the site to allow necessary corrections to be applied at the water tank whenever found to be advisable.

In the caisson work the water was measured in a closed tank directly connected to the city water supply and equipped with a check valve which closed when the tank was filled. The tank was filled and discharged through a three-way valve, the quantity discharged being regulated by means of a movable pipe. Owing to the inherent deficiencies of this style of tank this device was not particularly satisfactory and it was necessary to make considerable allowance to ensure that the specified water ratios were not exceeded.

On the superstructure, the water-measuring device consisted of a calibrated open tank provided with an adjustable overflow pipe which prevented more water being let into the tank than was required for the batch. This device permitted quite accurate measurements of the water, but corresponding accuracy was not gained in measuring the aggregates, which were measured in buggies in fractional quantities. This condition led to some variation in strength.

As a result of studies of the moisture content of the aggregates, determined by weighing and drying, and by means of an experimental apparatus for measurement by displacement, it was found that the moisture content did not vary sufficiently to seriously affect the actual working of the water-cement ratio. It is not thought that variations in water content would prove embarrassing on the average job.

In the caisson work 3·33 cu. ft. of cement were used per cubic yard of concrete showing an average strength of 2880 lbs. per sq. in. at 28 days. This was reported to be about 1 cu. ft. per cubic yard less than was usually used on that class of work. This saving was effected through the use of consistencies much stiffer than is the usual practice and comparatively large aggregate. The aggregate was graded up to 1½ in. The consistency was, however, at no time too stiff for proper placement. Each caisson shaft, 70 to 75 ft. in depth, was placed continuously in three to four hours with no water appearing on the surface, although the surface was at all times plastic. During the half-hour needed for placing the dowels at the top, a man standing in the concrete would gradually sink to a depth of 6 to 10 in., and small quantities of water would show in spots.

In the superstructure the average proportion of cement was 5·75 cu. ft. per cu. yd. of concrete. Of the total yardage, about 40 per cent. was of the 6-gallon water-ratio class and 60 per cent. was of the 7½-gallon water-ratio class.

The tendency to use too little coarse material can easily be controlled by the specification of a suitable minimum ratio of coarse to fine. The following table of limiting aggregate proportions is suggested for the ordinary range of materials to be used with a water-cement ratio strength specification, where it is required that the mixes be such that they can be readily puddled into place without excessive spading and without harshness or honeycombing.

Size of Coarse Aggregate, Inches.	Ratio of Coarse to Fine on Basis of Dry Compact Volumes.	
	Minimum.	Maximum.
⅜	0·4	0·8
¾	0·6	1·5
1 and over	1·0	2·0

The slump test was not used as a governing test for workability, but only to reveal changes in the nature of material that would render other proportions advisable. It will show unsuspected changes in proportioning and in water content, as the test is very sensitive to such changes.

In estimating the probable amount of aggregates and cement to be needed under such a specification no particular difficulty need be feared. After a little experience with this type of control the contractor can easily use the usual tables of quantities and determine the quantities of materials to be required. A few trial batches may be advisable in case of doubt, especially where a new source of materials is to be encountered. With the water-cement ratio fixed, the most important factor affecting the quality of the concrete is the consistency or fluidity of the mix. The contractor must determine for himself what mix he will find necessary with the given materials to produce the consistency which he will require.

The essence of the water-cement ratio specification consists only in the establishment of definite water-ratios with the single qualification that aggregates be used in such quantities and combination as will give workable mixes. When mixes which are plastic and workable are used with these water-ratios, the strengths indicated should be obtained with a fair degree of accuracy. Likewise, as found on the work covered by the paper, the quantities of cement shown for the different mixes are quite accurate for materials of the same character and assumed conditions as those used as a basis for the tables. Bulking of 25 per cent. for the sand and 8 per cent. for the gravel as due to moisture content and method of measurement were assumed. For different grading of aggregates and for different degrees of bulking the cement quantities will not be the same.

At the same Convention Mr. McMillan detailed the method of applying the cement-water principle of proportioning to smaller concrete works. *Fig.* 2 is a curve, prepared by Professor Duff Abrams and Mr. Stanton Walker, of cement-water ratios recommended for constructional works where conditions and inspection may be such that an extra margin of safety is desirable. To get concrete of any desired strength, select from the curve the amount of mixing water to use for that particular strength. Then mix sand and stone as desired until the required consistency is obtained, using all the time the correct ratio of cement as found from the curve. When sand or coarse aggregate contains moisture the water to be added at the mixer will be the amount shown by the curve less that carried by the aggregate, as indicated in Note 2.

The more aggregate that can be added to a given quantity of cement and water, the more economical the concrete, the limit being that the mix must not be too dry or stiff to place readily.

Thus: If concrete having a strength of 1800 lbs. per sq. in. is desired, the curve shows that the total water required is 7 galls. per cu. ft. of cement. If moderately wet sand and dry crushed stone be used as aggregate, a batch should be made of, say, 1 cu. ft. cement, 2 cu. ft. sand, and enough coarse material to produce the desired consistency. According to Note 2 2 cu. ft. of wet sand will carry 1 gall. of water, which should be deducted from the quantity shown by the curve as being necessary (7 galls. – 1 gall. = 6 galls.). If to get the desired workability it were found necessary to use more or less sand, the water to be added at the mixer would have to be altered accordingly: thus, if 2½ cu. ft. of sand were used, the extra ½ cu. ft. of sand would contain ¼ gall. of water, and only 5¾ galls. would be added.

Modern Road Constructional Methods.

Advantages of the All-Concrete Road.

By S. E. BURGESS, M.Inst.C.E., L.R.I.B.A.
(*Borough Engineer, Architect and Surveyor, County Borough of Middlesbrough.*)

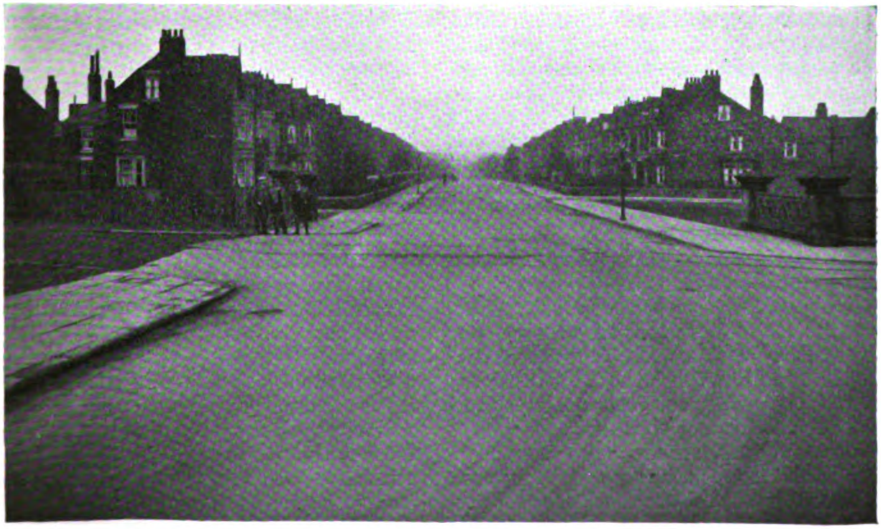
Large sums of money have been spent, and must necessarily continue to be spent in succeeding years, for the reconstruction of the roadways of the country. Increasingly very heavy traffic is daily experienced, and will demonstrate to City and Borough Engineers that existing road structures of bygone methods of construction are quite inadequate to meet modern requirements.

In the busy centres road construction has hitherto, in a measure, been successfully carried out by providing a mass concrete foundation of varying thickness, in some cases for heavy-traffic as much as 10 in., 12 in. and 14 in. in thickness, paved with granite or other blocks and setts or with hard or soft wood blocks. Even in these cases, where one would have thought such construction was sound, experience has shown that the setts crack and crumble, and the foundation sinks so much that on examination it is found that even the concrete substructure underneath the substantial paved surface is fractured—all this by reason of the super-imposed increasing weight and speed of present-day road traffic.

Macadam roads, either water-bound tar-macadam or other bitumastic solution methods, sooner or later deteriorate under the frequency of such heavy and fast traffic, a continuity of corrugations is formed, and pot-holes all over the surface are innumerable.

Notwithstanding all this, to some extent the tendency has been to carry on in the same old-fashioned way and in some measure to resign ourselves to heavy annual maintenance costs that are considered unavoidable. In my opinion there is no necessity for the country to be saddled with enormous expenditure for annual upkeep and maintenance of roads. Wherever the traffic gets beyond the normal, and any road by reason of such traffic becomes an important one, a proper foundation — preferably of Portland cement concrete—should be laid and reinforced with steel fabric reinforcement.

As regards road construction work which is being carried out at Middles-



Southfield Road : Reinforced Concrete Road at Middlesbrough.

brough, the Corporation, to my order and supervision, since 1921 to the present time has reconstructed a length of over 11 miles of street and road work all in reinforced concrete. My specification for the reinforced concrete roads is as follows :—

Portland cement concrete to be 6 in. to 8 in. thick, reinforced with steel fabric.

Weight of steel : Single layer, 6 lbs. per sq. yd. ; Double layer, as specified, 10 lbs. per sq. yd.

All roads with heavy traffic, double layer ; in other or secondary roads single reinforcement is laid.

The reinforcement is laid from 1½ in. to 2 in. from the bottom or underside of the concrete surface foundation, with a camber of generally 1 in 50.

The concrete is gauged 4½ to 1, composed of 3 parts clean Whinstone chippings, 1½ to 1¼ gauge ; 1½ parts coarse pit sand thoroughly cleaned ; and 1 part British Portland cement—all measured by volume.

The concrete for many of our works has been mixed by hand, having regard that the work is done for the employment of as much labour as possible. The hand-mixed concrete is turned over on a banker twice dry and twice wet, water sprinkled, the mixture being kept as dry as possible so long as it is workable. In many cases concrete mixers are used. Ground, if too dry, is soaked with water before the concrete is laid.

Concrete, when left overnight, is finished with rough and somewhat straight vertical edge across the road—this is only carried out at the end of the day's work. The concrete in the daytime is carried out in bays continually in lengths of 12 ft., and a straight vertical edge across the road is made. The steel reinforcement is carried 12 to 18 in. beyond the joint in order to bond with the next bay, the bonding, of course, taking place while the concrete is green.

All the concrete is laid in a solid mass in suitable layers one on top of the other so that it is bedded and incorporated the full thickness while green, and finally struck off with wooden templates and finished with tamper beaters.

Concrete, when left overnight, is covered with tarpaulins ; next day it is covered with sand, which is kept wet for a fortnight afterwards, when it is found that the surface is rigidly set, and a week or so afterwards the road is opened for traffic.

This, generally, is the method of laying as carried out at Middlesbrough, and we have roads that have been completed for over six years, which as yet have not been surface treated in any way, and they are standing up very well, even up to and abutting the rails where tramway lines are laid.

In some instances a start has been made with the painting of the surface of the concrete, which is done with a mixture of hot pitch and tar, care being taken that the surface of the concrete is thoroughly clean and swept before this is applied. On the surface so painted a final top dressing of fine gravel or granite chippings is carried out. The carpet or coat of tar and bitumen painting and top dressing is undertaken for the maintenance and repair of reinforced concrete roads, and this is done to suit the varying traffic condition of the different roads, in some cases once a year, in other cases once in two years, others once in three years, and even only once in four years. The cost of this painting and top dressing for roads annually painted works out at 5*d*. to 6*d*. per yard for maintenance per annum ; those painted every two years, 2½*d*. to 3*d*. per square yard per annum ; those painted every three years, 1⅔*d*. to 2*d*. per square yard per annum.

All the work at Middlesbrough has been carried out by labour obtained from the Employment Exchange with the help of a small percentage of Corporation men who are accustomed to the laying of concrete (these latter men act in the capacity of gangers—the percentage being 1 in 10). The labour supplied by the Employment Exchange is not skilled and the men are changed every week.

The roads carried out are proving to be very substantial and satisfactory. The concrete is laid the full width of the carriageway in continuous order longitudinally. In the setting there is slight contraction which has caused cracks here and there—these are not considered detrimental. To prevent water getting in and thereby rusting the reinforcement, a mixture of hot pitch and tar is run into the cracks. This will be entirely avoided after the roads have received their first coat of tar and bitumen painting and top dressing, as such maintenance of the roads will cover the concrete surface.

Morton to Middlesbrough Road, for the Yorkshire County Council.

The concrete roads painted as described give the appearance of a high-class tar-macadam road without the slightest risk or fear of corrugation, and such tar-macadam finish is the thin layer of surface painting as described. There is no likelihood of corrugations, as the concrete structure is itself the weight-bearing constructed road; the surface painting effectually water-proofs the concrete, and it will be noted that solidity is brought right up to the running surface of the road. Hammering by heavy and fast motor traffic, known as "hammer-rammer," cannot be made, and corrugations in any form are prevented.

To May, 1926, £300,000 has been expended by the Corporation on concrete roads. In many cases they are semi-arterial roads, i.e. ring roads joining up important and main radial roads. Main arterial roads are also concreted, and many tributary and side roads have also been reconstructed in the same manner.

In my opinion, steel fabric reinforcement is necessary to strengthen the concrete so that the thickness or depth of the concrete shall be reasonable; otherwise, for equal strength of an 8 in. depth of concrete reinforced with a double layer steel fabric reinforcement, for a concrete road without reinforcement a thickness of at least 2 ft. would be required, whereas by the insertion of the fabric the lesser thickness is attainable. Tests show that proper reinforcement increases the strength of the concrete 3 times.

In my opinion, reinforced concrete roads are satisfactory. We are getting good results. I anticipate that even this will be further improved by scientific application of the reinforcement by diagonal stress and shear members. The price per square yard, all-in, including labour, material, reinforcement, etc., at Middlesbrough is 17*s*. to 20*s*. per square yard. We are entirely satisfied at Middlesbrough with the concrete roads that have been laid; so much so, that a continuation of the same will go on. Many deputations have inspected these concrete roads and expressed satisfaction with all they have seen in connection therewith.

Rapid Cottage Construction.

HOUSE BUILT IN 4½ DAYS.

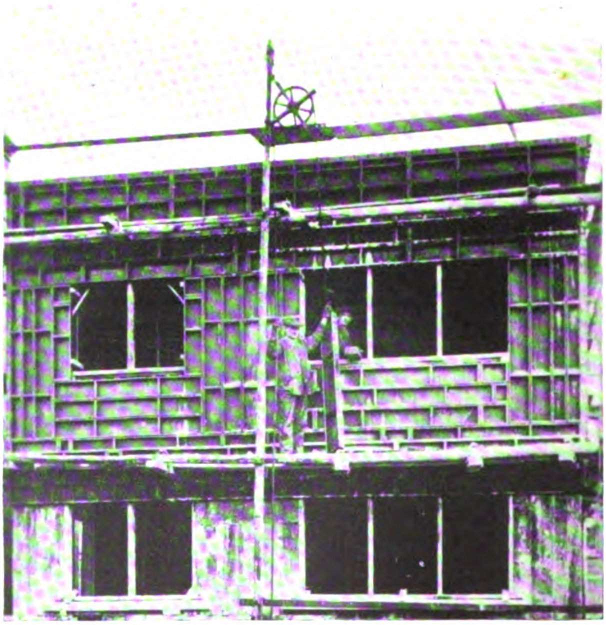
CONSIDERABLE interest has been aroused by the construction of a concrete house, complete, in four-and-a-half days, which took place in Horseferry Road, London, last month.

The method adopted was an American one, in which the walls and floors are poured monolithic with the use of a continuous mixer from which the concrete is conveyed by elevator to a chute which deposits the material direct between the steel shuttering.

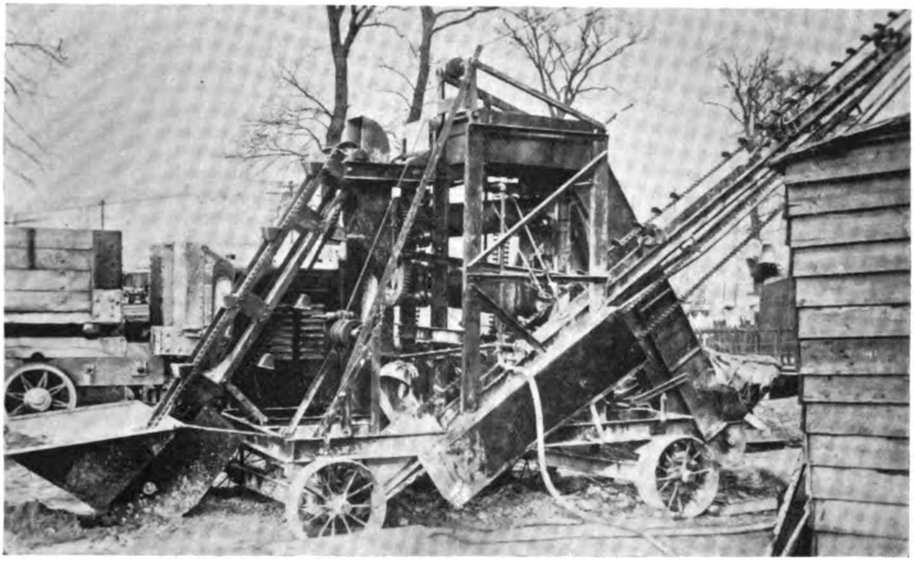
The foundations are standard practice, designed to suit the local conditions. A floor slab 6 in. thick is then poured, 12 in. longer and wider than the outside dimensions of the house, in which two-way reinforcement is placed, spaced as necessary, the extra 12 in. providing a ledge on which to set up the outer wall forms. The positions of the main and partition walls are set out with chalk lines, on which the light steel forms are clipped together, one story at a time, and clamped in place.

The concrete is poured into this steel mould, and the structure is thus cast monolithic, one complete story being poured at a time, including walls, floors, partitions, roof, cornices, etc. The forms used in making the belt-course act as a base for the second story forms, and are held in place by the reinforcement in addition to the clips and angle braces. The same forms which compose the lower story are employed in building the second story.

The forms consist of a number of standard sizes so designed as to enable any dimension in any direction in differences of 3 in. to be obtained, by bolting the forms together in the required manner. When smaller dimensions have to be considered, this may be effected by bolting filler-pieces to the flanges. They are manufactured (6 in. and 9 in. wide) from light steel strips of No. 12 gauge, in lengths of 6 in., 9 in., 12 in., 2 ft., 3 ft., 4 ft., and 6 ft. The standard unit which is chiefly used measures 6 ft. long by 9 in. wide, with 3-in. flanges on both sides and both ends. The flanges are punched with two rows of $\frac{9}{16}$ in. square holes on 1½ in., 3 in. and



Top Story Completed Ready for Stripping.



Mixing and Elevating Plant.

6 in. centres. This provides for setting the unit in either vertical or horizontal position and registering accurately with each adjoining unit; the two rows of holes also permit making offsets, pilaster effects, panels, or water-tables. Besides the 9 in. and 6 in. series of wall forms, the system includes inside and outside corners, and floor-release units made in various lengths.

Another feature is that the forms are designed to allow for "creep," and for this reason they are made $\frac{1}{16}$ in. shorter in length and $\frac{1}{16}$ in. narrower in width than the nominal dimensions. It is claimed that in practice no concrete leaks between forms, even when the spaces are $\frac{1}{16}$ in. or somewhat over.

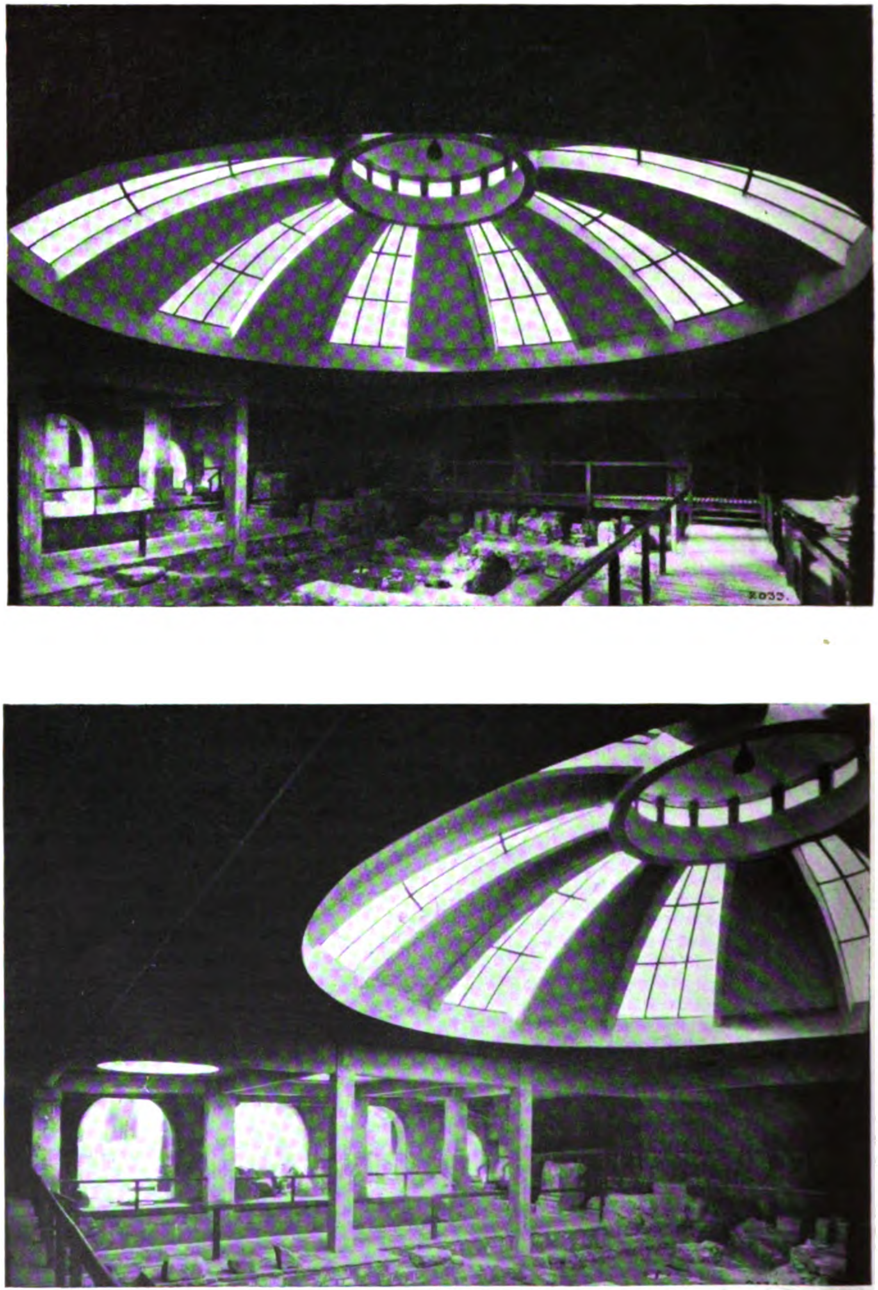
A clinker concrete is used, the outer face of which is waterproofed with Portland cement stucco.

The mixer is of the continuous type specially designed to minimise labour and secure continuity. The materials are thrown into a bin from which they are fed into the mixer by elevators. Water supply is from an overhead tank which automatically regulates the quantity. On emerging from the mixer, the concrete is guided into a trough from which it is picked up by an elevator which keeps the material constantly agitated until it reaches the top, from whence it is poured through a pipe into the forms.

The system, known as the "Gavin-Lambie," is in the hands of the International Housing Trust, Ltd., of Abbey House, Victoria Street, S.W.1.

Large Concrete Factory Contract.

THE new works for the Michelin Tyre Co., at Stoke-on-Trent, will be erected by Messrs. Peter Lind & Co., of Westminster, in collaboration with Messrs. Saxild & Partners, of Westminster. The contract value will be well over £300,000, and the work to be undertaken includes: A multi-story reinforced concrete building with 45,000 sq. ft. floor area; several single-story buildings covering a ground area of 400,000 sq. ft.; boiler and power house with overhead coal bunker, in reinforced concrete; building containing nine underground petrol storage tanks; reinforced concrete enclosure wall 10 ft. high by 3,000 yds. long. The design and details of all the reinforced concrete work will be prepared by the contractors' own staff to the approval of the company's architects, Messrs. Wallis, Gilbert & Partners. The work will be started at once.



Figs. 3 and 4.—Views of Completed Covering. (*See p.* 505.)

Covering over Kingston Baths, Bath.

THE particular section of the remains of the Roman thermæ at Bath which this covering protects from the elements is of great interest to archæologists. The site was first excavated in part in 1755 by the Duke of Kingston, but the excavations were only taken down sufficiently far to enable him to get foundations for the erection of his house. The discoveries were then planned for him, but again covered up by the new house, and, it is feared, some of the Roman work used in the new building, and all trace of the ancient work was again lost to view for 150 years.

Within the last few years, however, the site has again been excavated; fortunately greater care was taken in the work of exploration, and two earlier Roman levels below that reached in 1755 were disclosed. Originally this portion of the site accommodated two rectangular swimming baths parallel to each other, running north and south, and both filled by connecting culverts from the great rectangular bath to the west. The Romans first of all "shallowed" one of the swimming pools by putting in a second floor, taking care first to remove the lead lining of the original bath, and then paved the upper floor with big flagstones. The second bathing pool was entirely filled in during the Roman occupation and converted from a water bath into a series of hot-air baths at a level of about 4 ft. 6 in. above the floor of the pool. Again, at a still later period, these hot-air baths were covered over, the general level raised, and another series of hot-air baths constructed, with the necessary furnaces and heating flues.

To-day these can be seen in a remarkably good state of preservation, and the work of all three periods can be followed quite easily. Bearing in mind that these baths were probably commenced about the year A.D. 54, and were used throughout the Roman occupation, it is not surprising that the Romans found it necessary to make alterations and improvements during the 400 years or more, but it is interesting to know that we have in our midst such an example showing the continuity of the use of the baths of Bath

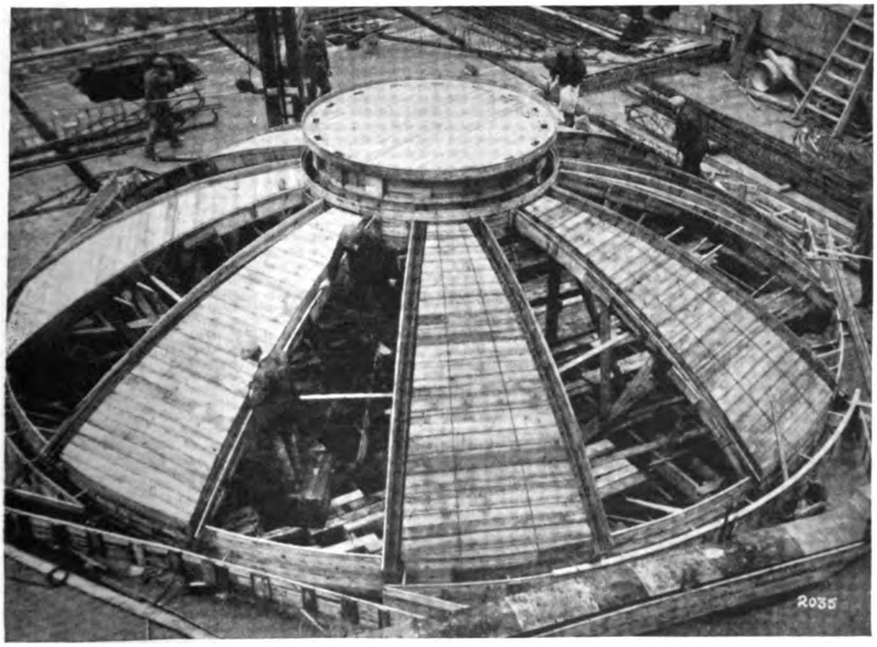


Fig. 1.—Shuttering in Position for Dome.

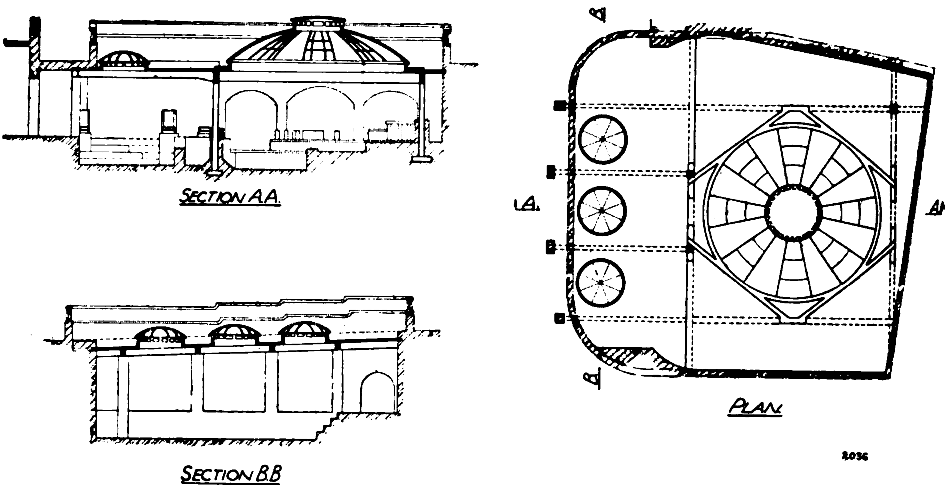


Fig. 2.—Details of Construction.

by the Romans, and that these remains are preserved for the present generation to see after having been buried for over 1,300 years, that is, from the time of the destruction of the Roman city of Aquæ Sulis in 577.

The covering, as will be seen from the drawing, is roughly square in plan, the measurements being approximately 72 ft. in each direction. It consists of a flat roof, the principal feature of which is a large dome, and with the exception, of course, of the glass lights, the whole of the work is constructed of reinforced concrete. The covering is supported on a series of main and secondary beams spanning between existing brick walls and piers, with reinforced concrete columns introduced where necessary. Special provision is made for supporting the large dome by the construction of beams spanning across the corners of the square formed by the main beams and monolithic with the ring beam which forms the base of the dome.

The dome is 35 ft. wide at its base, and its height at the roof level is approximately 10 ft. The ribs of the dome consist of arched beams with spandril slabs between, a rebate being formed along the top outer edges of the ribs to accommodate the lights. The top light is 9 ft. wide and 2 ft. 9 in. deep. It consists of a ring beam spanning between the ribs with reinforced concrete mullions and roof slab. The remaining reinforced concrete work consists of the seatings for the three small lights shown on the left of the plan. These are each 9 ft. 6 in. wide and consist simply of ring beams supported by the roof slab. The whole of the work presents a very good appearance and serves its purpose admirably, the remains beneath being exceptionally well lit by the adoption of this method of covering.

The architect responsible for the whole of the work was Mr. A. J. Taylor, F.R.I.B.A., of Bath, from whose outline drawings the Indented Bar and Concrete Engineering Co., Ltd., prepared the reinforced concrete details. The contractors for the work were Messrs. F. J. Amery & Sons, of Bath.

Concrete Houses at Hull.

THE Hull Corporation Housing Committee has sanctioned the erection of another four-hundred concrete houses on the East Hull Estate, to be built on the "Winget" pier-and-panel system. This makes six-hundred houses of this type which are being built on this site, the first two-hundred—many of which are already completed and occupied—having been started last autumn. At Wakefield, where this system was first adopted, the Corporation's original contract in 1924 was for two-hundred houses; a second instalment of two-hundred was put in hand in 1925, and this has been followed during the present year by an additional five-hundred. The Norwich Corporation, which put in hand its first hundred houses on this system by direct labour a year ago, has this year completed another contract for a second hundred.

Parabola Construction.

By **W. A. GREEN, M.A., B.Sc., A.M.Inst.C.E.**

THERE are many methods for plotting a parabola, but none that the writer has seen published is based on the principle that the parabola is the curve of equilibrium for a uniformly distributed load. The application of this principle leads to the simplest construction known to the writer.

If it is required to draw a parabola through a point A and tangential to a line *BC* at the point *B*, the axis being vertical (see *Fig.* 1), it is obvious that the tangent to the curve at *A* must pass through the point *D* on the line *BC* midway between the verticals through *A* and *B*, because the tangents at the ends of an equilibrium curve for a distributed load must intersect on the vertical through the centre of the load.

The tangent to the point common to the curve and the vertical through *D* must similarly bisect *DA* and *DB*. If therefore $AE = ED$ and $DF = FB$ and *EF* intersects the vertical through *D* in *G*, then *G* is a point in the parabola and *EF* is the tangent at *G*. It should be noted that *EF* is parallel to the chord *AB* and that the vertical *DK* from *D* to the chord is bisected by *G*.

A point on the parabola in any vertical *RS* may be similarly found, as the tangent through it must bisect the line *BR* and *GS* (also *AU*).

Hence *P* is found by bisecting *BR* in *Q* and *GS* in *T* (or *AU* in *V*) and then joining *QT* (or *QV*) and producing it to cut *SR* in *P*.

If the direction of the axis (shown vertical in the drawings) and three points *A B* and *C* are given (see *Fig.* 2), the tangent to the curve at *A* and *B* must meet on the vertical halfway between them.

If *E* lies on *AD* halfway between the verticals through *A* and *C*, and *F* lies on *BD* halfway between the verticals through *B* and *C*, and *FE* produced cuts *AB*

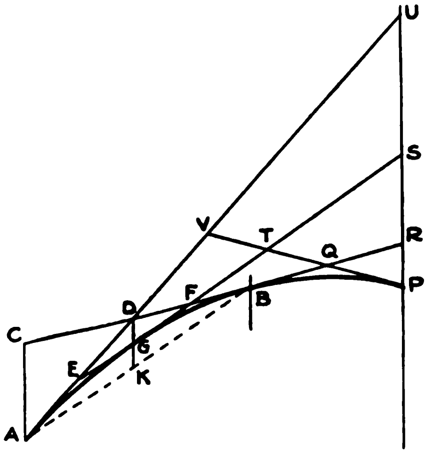


FIG. 1.

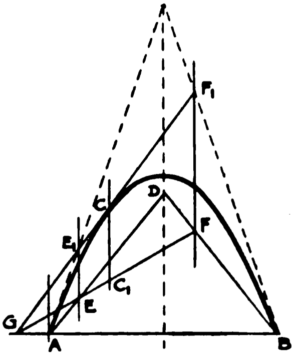


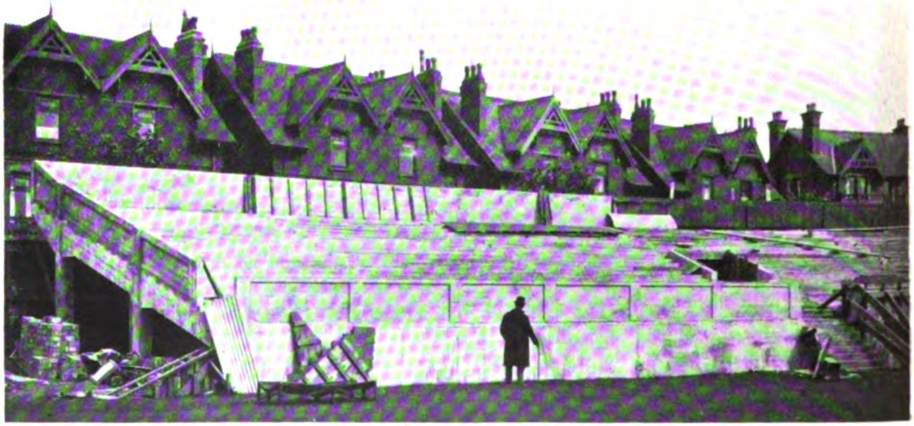
FIG. 2.

in G, then GC is the tangent to the parabola C. The rest of the construction is as before.

That GE_1F_1 is the tangent to the parabola through C will be evident when it is noted that all parabolas on the base AB with vertical axes are the same curves drawn to different scales, and that by the construction GEF is the tangent to a parabola drawn through C_1.

Institution of Civil Engineers.

THE Council of the Institution of Civil Engineers has made the following awards in respect of papers read and discussed at the ordinary meetings during the session 1925–1926: A Telford Gold Medal to Mr. O. L. Prowde, B.A., M.Inst.C.E. (Makwar, Sudan). A Watt Gold Medal to Mr. H. R. Lupton, M.A., Assoc.M.Inst.C.E. (Leeds). Telford Premiums to Messrs. A. S. Angwin, D.S.O., M.C., B.Sc.(Eng.), Assoc.M.Inst.C.E., and T. Walmsley, B.Sc.(Eng.), Assoc.M.Inst.C.E. (London); V. Bayley, C.I.E., M.Inst.C.E. (London); C. F. Bengough, M.Inst.C.E. (Tewkesbury); A. Honeysett, Assoc.M.Inst.C.E. (London); J. N. Reeson, M.Inst.C.E. (Melbourne, Victoria); and H. A. Reed, M.Inst.C.E. (Manchester). A Crampton Prize to Colonel G. R. Hearn, C.I.E., D.S.O., R.E., Assoc.Inst.C.E. (Calcutta). The Council have also awarded the Coopers Hill War Memorial Prize for 1925 (consisting of a bronze medal, parchment certificate, and a sum of money) to Mr. E. L. Everatt, A.M.Inst.C.E. (Bombay). This prize was founded by the Coopers Hill Society in memory of Coopers Hill men who lost their lives in the war.



Mr. H. H. Goodall, L.R.I.B.A., Architect.

Reinforced Concrete Stand at Trent Bridge.

[This photograph shows one of the new reinforced concrete grand-stands at the Trent Bridge Ground of the Notts Cricket Club practically completed. As mentioned in our May issue, in which plans and sections were given, the stand was completed in about two months, rapid-hardening Portland cement being used to expedite the work in order that it should be ready for the first Test Match.]

Design of Reinforced Concrete Members.

Bending and Compression.

By OSCAR FABER, O.B.E., D.Sc., M.Inst.C.E.

(Concluded.)

When a member is subject to a compressive force or forces the resultant of which do not lie on the centroid or centre of gravity of the section, they have to resist a moment as well as the direct stress.

If e is the distance of the resultant force P from the centroid, then the moment is

$$M = eP$$

This is the way the problem is usually presented, say with a load resting on a bracket.

Conversely, when M and P are known,

$$e = \frac{M}{P}$$

which gives the distance of the resultant from the centroid.

Case I: When the Eccentricity is so Small that no Tension is Developed in the Member.

This requires e to be less than $\cdot 166d$ for non-reinforced members, and in reinforced members the limit depends on the percentage and position of the reinforcement, but in usual practical cases may be taken as limited to about $e < \cdot 25d$.

The direct stress, uniform over the whole area, is

$$c = \frac{P}{A_E}.$$

Where A_E is the equivalent area, *i.e.* the area of concrete plus $(m - 1)$ times the area of steel

$$A_E = bh + (m - 1)\,A$$

The bending stress at the edge is given by

$$c = \frac{My}{I_E} = \frac{M}{Z_E}$$

Where M is the moment,

y is the distance of the edge from the centroid.

I_E is the equivalent moment of inertia of the section, that is, the moment of inertia of the section, after replacing each area of steel with $(m - 1)$, its area of concrete.

Z_E = equivalent modulus of the section $\dfrac{I_E}{y}$.

For unsymmetrical sections, the distances, y, of the edges may be dissimilar, and the combined stresses at the edges will be given by

$$c_1 = \frac{P}{A_E} + \frac{My_1}{I_E}$$

$$c = \frac{P}{A_E} - \frac{My_2}{I_E}$$

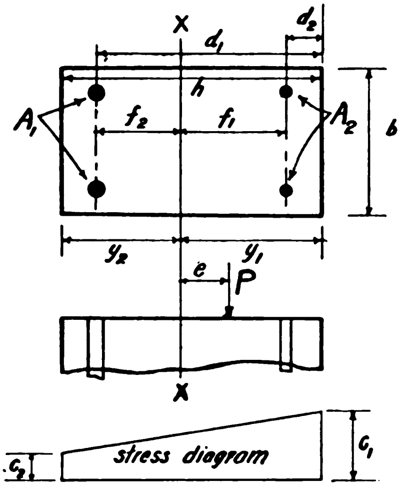


Fig. 4

The position of the centroid is given by

$$y_1 = \frac{\frac{bh^2}{2} + A_1(m - 1)d_1 + A_2(m - 1)d_2}{bh + A_1(m - 1) + A_2(m - 1)}$$

In the case of a rectangular section, symmetrically reinforced, the centroid is central, and $y_1 = y_2$.

Example of a Symmetrical Section.—A column, 18 in. × 12 in., with 4 1½-in. rods, having 1½ in. cover of concrete, has a load of P = 100,000 lbs. and a moment of M = 200,000 in. lbs. about its shorter axis. Calculate the stresses.

Solution.—In Fig. 4, $h = 18$, $d_1 = 16$ in., $d_2 = 2$ in., $A_1 = 3{\cdot}52$, $A_2 = 3{\cdot}52$, $b = 12$. The equivalent area—

$$\begin{aligned} A_E &= bh + (m - 1)\,A \\ &= 18 \text{ in.} \times 12 \text{ in.} + 14 \times 4 \times 1{\cdot}76 \\ &= 216 + 98{\cdot}6 \\ &= 314{\cdot}4 \text{ in.}^2 \end{aligned}$$

The equivalent moment of inertia—

$$\begin{aligned} I_E &= \frac{bh^3}{12} + (m - 1)\,Af^2 \\ &= \frac{12 \times 18^3}{12} + 14 \times 7{\cdot}04 \times 7^2 \\ &= 5840 + 4850 \\ &= 10{,}690 \text{ in.}^3 \end{aligned}$$

$$\begin{aligned} c_1 &= \frac{P}{A_E} \times \frac{M \times \frac{h}{2}}{I_E} \\ &= \frac{100{,}000}{314{\cdot}4} + \frac{200{,}000 \times 9 \text{ in.}}{10{,}690} \\ &= 319 + 172 = 491 \text{ lbs./in.}^2 \end{aligned}$$

$$\text{and } c_2 = 319 - 172 = 147 \text{ lbs./in.}^2$$

EXAMPLE OF AN UNSYMMETRICAL SECTION.—Let us repeat the last example, but with the steel on the more highly compressed side omitted, as would be the case in a singly reinforced section. The section is then unsymmetrical. In *Fig.* 4, $h = 18$, $b = 12$, $d_1 = 16$, $A_1 = 3{\cdot}52$, $A_2 = 0$.

The first thing is to find the distance of the centre of gravity from the compressed face. Let this be called g. Taking moments of the areas about the compressed edge, we have

$$bh \times 9 \text{ in.} + A + (m - 1) \times 16 \text{ in.} = A_E \times g$$

substituting

$$\begin{aligned} bh &= 18 \times 12 = 216 \text{ in.}^2 \\ A &= 3{\cdot}52 \text{ in.}^2 \\ A_E &= bh + A(m - 1) \\ &= 216 + 14 \times 3{\cdot}52 = 256{\cdot}4. \end{aligned}$$

We have

$$\begin{aligned} g &= \frac{216 \times 9 + 3{\cdot}52 \times 14 \times 16}{265{\cdot}4} \\ &= \frac{1954 + 789}{265{\cdot}4} = \frac{2743}{265{\cdot}4} = 10{\cdot}3 \text{ in.} \end{aligned}$$

The equivalent moment of inertia, I_E, which must be measured about the centroid—

$$\begin{aligned} I_E &= \frac{by_1^3}{3} + \frac{by_2^3}{3} + (m - 1)\,Af^2 \\ &= \frac{12 \times 10{\cdot}3^3}{3} + \frac{12 \times 7{\cdot}7^3}{3} + 14 \times 3{\cdot}52 \times 5{\cdot}7^2 \\ &= 4360 + 1830 + 1610 = 7800 \text{ in.}^4 \end{aligned}$$

$$\begin{aligned} c_1 &= \frac{P}{A_E} + \frac{My_1}{I_E} \\ &= \frac{100{,}000}{265{\cdot}4} + \frac{200{,}000 \times 10{\cdot}3}{7800} \\ &= 376 + 264 = 640 \text{ lb./in.}^2 \end{aligned}$$

$$\begin{aligned} c_2 &= \frac{P}{A_E} - \frac{My_2}{I_E} \\ &= \frac{100{,}000}{265{\cdot}4} - \frac{200{,}000 \times 7{\cdot}7}{7800} \\ &= 376 - 197 = 179 \text{ lb./in.}^2 \end{aligned}$$

If the problem were given differently, by stating the point at which P acts, then the centroid has to be determined before e and M can be calculated. Thus, if instead of being given M, we were told that the resultant force acted 3 in. inside the compressed face, then we should need to calculate the position of the centroid as above ($g = 10{\cdot}3$ in.), whence

$$e = g - 3 \text{ in.} = 7{\cdot}3 \text{ in.}$$

and

$$M = P \times e = 100{,}000 \times 7{\cdot}3 = 730{,}000 \text{ in. lb.}$$

CASE II: WHEN THE ECCENTRICITY IS SUFFICIENT TO PRODUCE TENSION, VALUES OF e UP TO $1{\cdot}6d$.

This case includes cases from about $e = {\cdot}25d$ (depending on the percentage of steel). The solution follows closely that given for bending and tension, and may, therefore, be given with less explanation. As before, a series of diagrams (8 to 14) are produced, from which actual design is very greatly simplified. These are calculated, as before, by assuming a definite value for n and r, and calculating

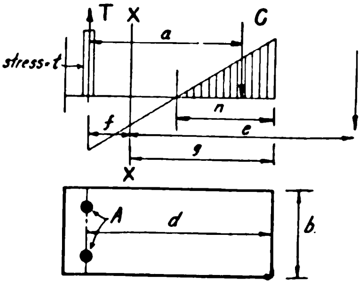


Fig. 5.

BENDING AND COMPRESSION

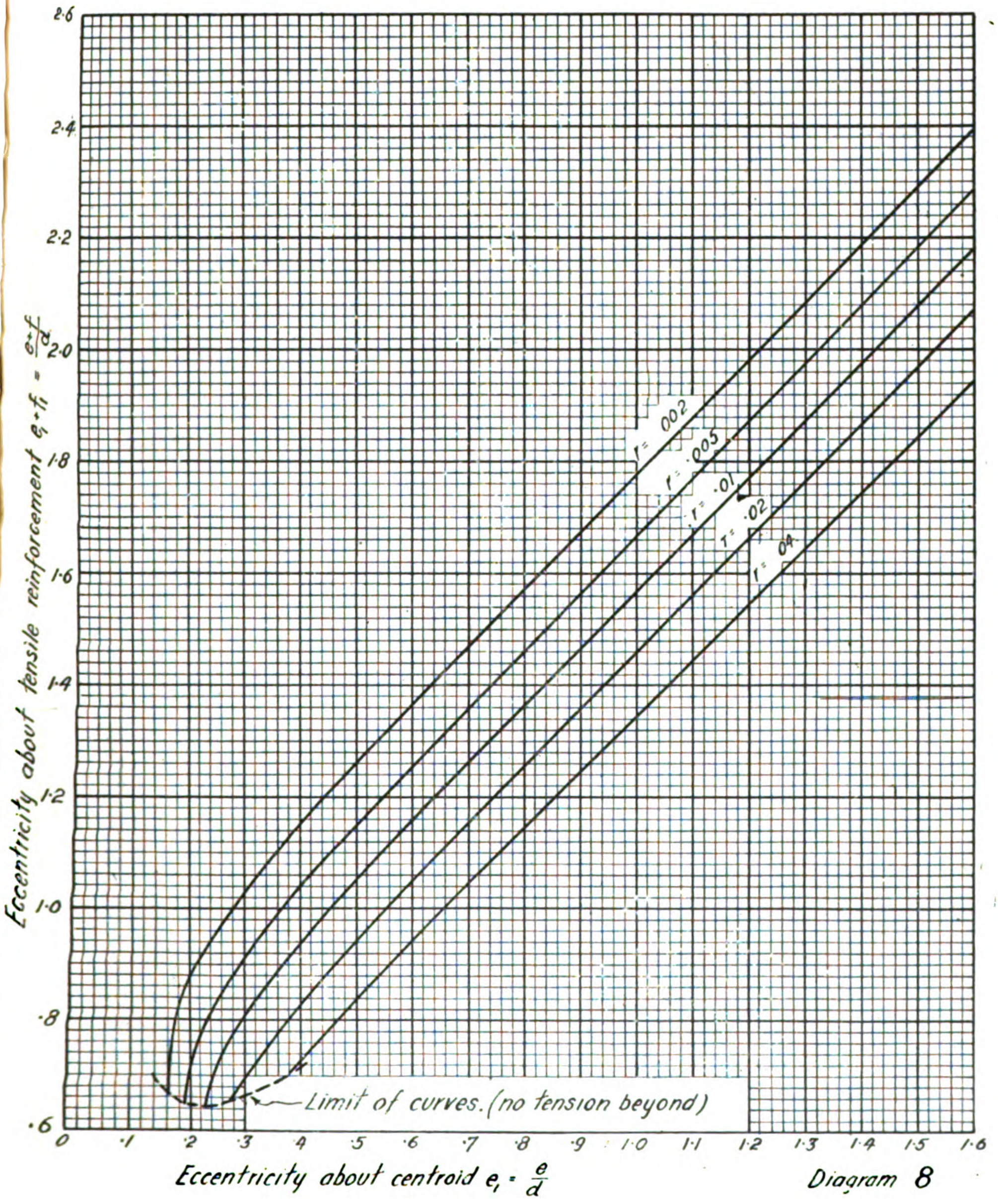


Diagram 8

BENDING AND COMPRESSION.

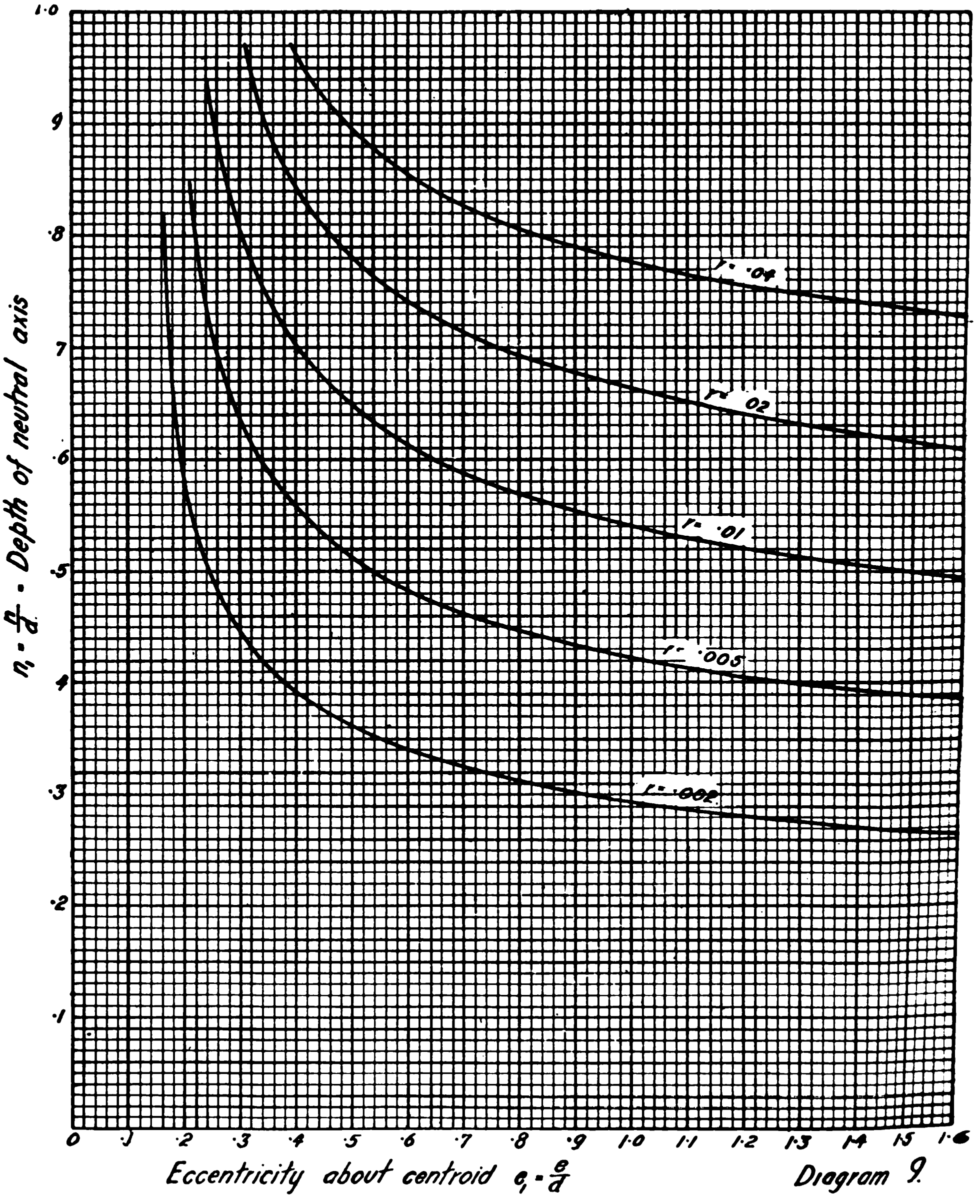


Diagram 9.

BENDING AND COMPRESSION

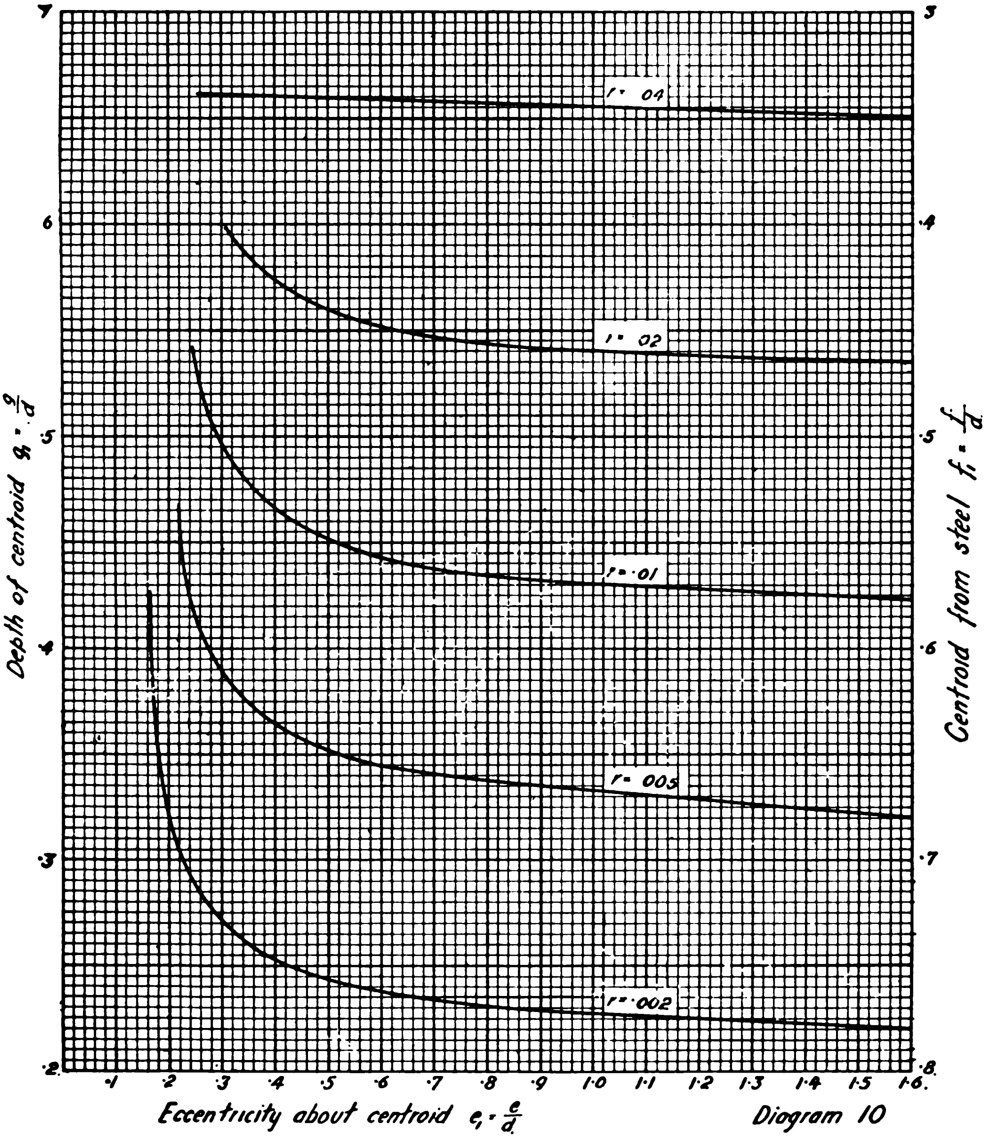


Diagram 10

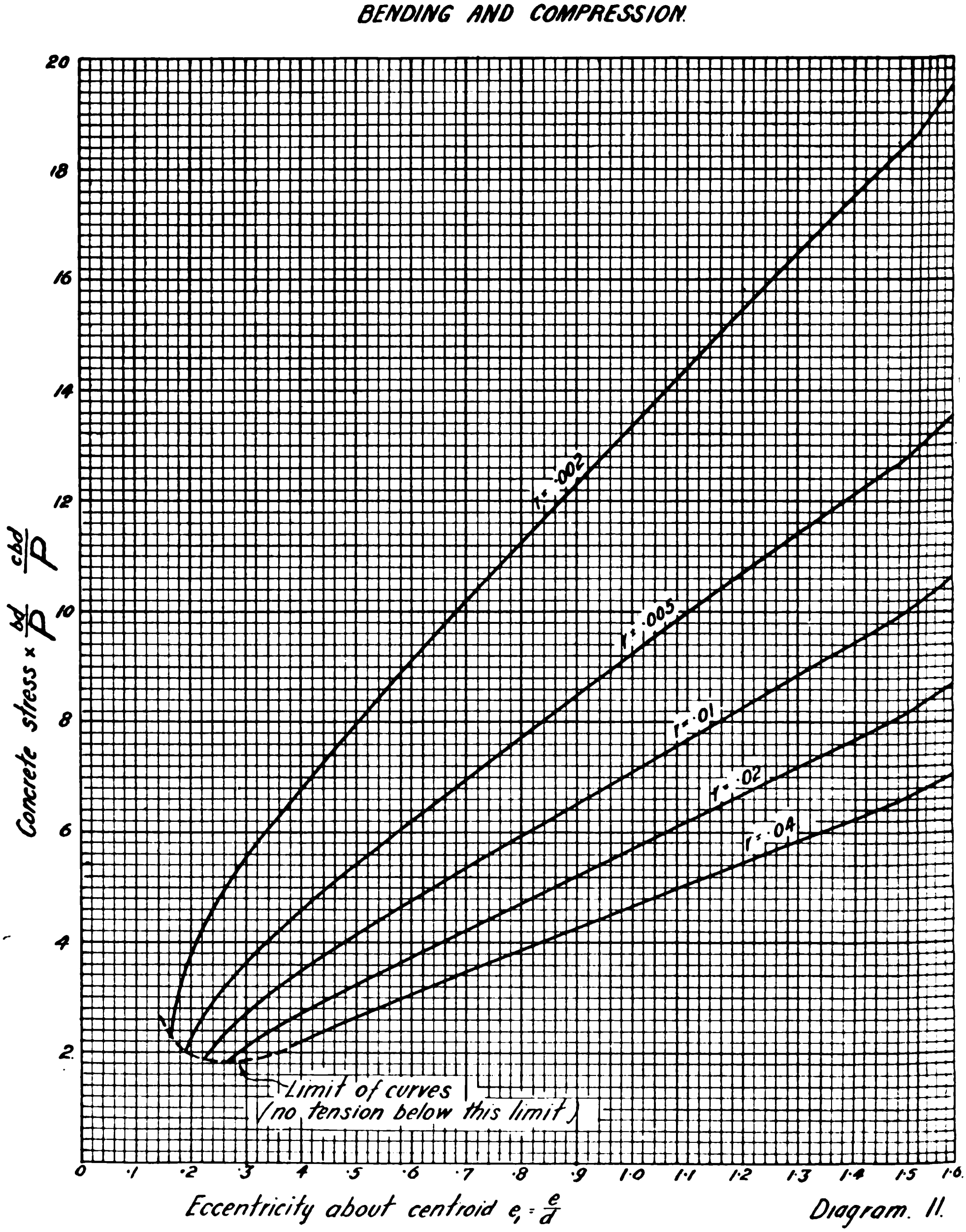

BENDING AND COMPRESSION.
Concrete stress × bd/P cbd/P
20
18
16
14
12
10
8
6
4
2
0
·1
·2
·3
·4
·5
·6
·7
·8
·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6
r = ·002
r = ·005
r = ·01
r = ·02
r = ·04
Limit of curves
(no tension below this limit)
Eccentricity about centroid $e_1 = \frac{e}{d}$

Diagram. II.

all the other quantities therefrom. Then, by a method of calculation exactly similar to that used with bending and tension, we derive the formulæ :—

Ratio of stresses :

$$t_1 = \frac{t}{c} = \frac{m(1 - n_1)}{n_1} \quad . \quad . \quad (1)$$

Depth of centroid :

$$g_1 = \frac{g}{d} = \frac{mr \times \frac{n_1{}^2}{2}}{mr + n_1} \quad . \quad . \quad (2)$$

Centroid from steel :

$$f_1 = \frac{f}{d} = \frac{n_1\left(1 - \frac{n_1}{2}\right)}{mr + n_1} \quad . \quad . \quad (3)$$

Radius arm :

$$a_1 = \frac{a}{d} = 1 - \frac{n_1}{3} \quad . \quad . \quad (4)$$

Tensile stress :

$$t = \frac{P}{A} \cdot \frac{(e + f - a)}{a} \quad . \quad . \quad (5)$$

Compressive stress :

$$c = \frac{2P(e + f)}{nba} \quad . \quad . \quad . \quad (6)$$

Line of thrust from steel :

$$e_1 + f_1 = \frac{e + f}{d} = \frac{a_1 n_1}{n_1 - 2rt_1} \quad . \quad (7)$$

Eccentricity about centroid :

$$e_1 = \frac{e}{d} = (e_1 + f_1 - f_1)$$

Tensile stress :

$$\times \frac{bd}{P}$$

$$\frac{tbd}{P} = \frac{t_1}{\frac{n_1}{2} - t_1 r} \quad . \quad . \quad (8)$$

Compressive stress :

$$\times \frac{bd}{P}$$

$$\frac{cbd}{P} = \frac{1}{\frac{n_1}{2} - t_1 r} \quad . \quad . \quad (9)$$

TABLE III

Bending and Compression.

Steel Ratio.	Depth of Neutral Axis.	Radius Arm.	Depth of Centroid	Centroid from Steel.	Eccentr. about Steel	Eccentr. about Centroid	Ratio of Stresses.	Steel Stress. × $\frac{bd}{P}$	Concrete Stress. × $\frac{bd}{P}$
r	n_1	a_1	g_1	f_1	$e_1 + f_1$	e_1	$\frac{t}{c} = t_1$	$\frac{tbd}{P}$	$\frac{cbd}{P}$
·002 .	·8	·7$\dot{3}$	·421	·579	·745	·166	3·75	9·55	2·55
	·6	·8	·33$\dot{3}$	·66$\dot{6}$	·857	191	10	35·7	3·57
	·4	·8$\dot{6}$	·255	·745	1·120	375	22·5	145·5	6·46
	·3	·9	·228	·772	1·69	·918	35	437·5	12·5
	·25	·91$\dot{6}$	·217	·783	3·27	2·487	45	1285	28·6
·005 .	·8	·7$\dot{3}$	·452	·548	·76	·22	3·75	9·85	2·625
	·6	·8	·378	·622	·96	·338	10	40	4
	·5	·83$\dot{3}$	·348	·652	1·188	·536	15	85·7	5·72
	·4	·86$\dot{6}$	·326	·674	1·98	1·306	22·5	257	11·45
·01 ..	·9	·7	·529	·471	·727	·256	1·6$\dot{6}$	3·75	2·31
	·8	·7$\dot{3}$	·495	·505	·809	·304	3·75	10·33	2·76
	·7	·7$\dot{6}$	·465	·535	·94	·405	6·43	22·5	3·5
	·6	·8	·44	·56	1·2	·64	10	50	5
	·5	·83$\dot{3}$	·424	·576	2·08$\dot{3}$	1·507	15	150	10
·02 ..	·9	·7	·5875	·4125	·756	·3435	1·6$\dot{6}$	4	2·4
	·8	·7$\dot{3}$	·563$\dot{3}$	·437	·901	·464	3·75	11·54	3·075
	·7	·7$\dot{6}$	·545	·455	1·21	·755	6·43	28·1	4·51
	·6	·8	·53$\dot{3}$	·46$\dot{6}$	2·4	1·93$\dot{3}$	10	100	10
·04 ..	·9	·7	·67	·33	·822	·492	1·6$\dot{6}$	4·35	2·61
	·8	·7$\dot{3}$	·65$\dot{6}$	·34$\dot{3}$	1·17$\dot{3}$	·83	3·75	15	4
	·75	·75	·653	·347	1·607	1·26	5	28·55	5·71

BENDING AND COMPRESSION

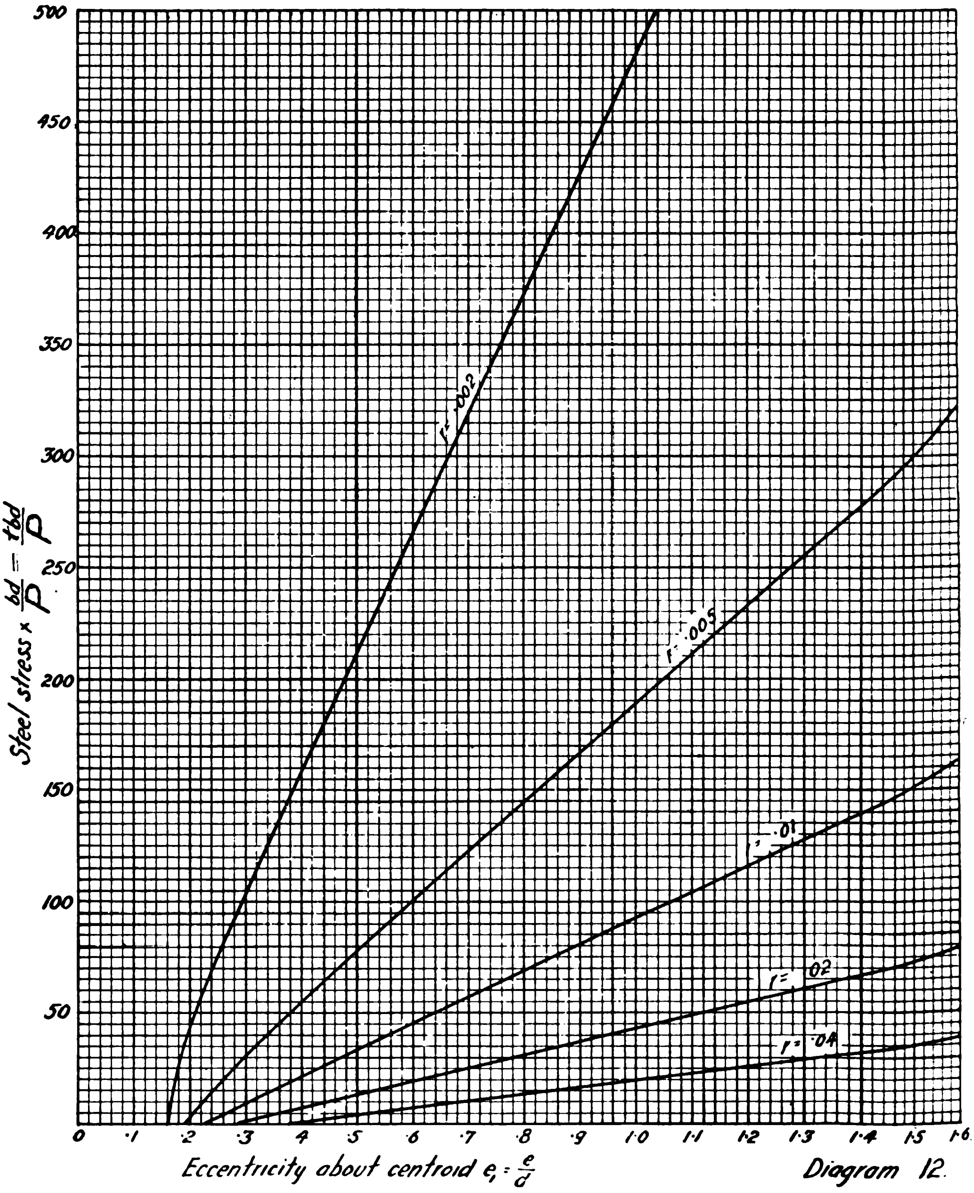


Diagram 12.

BENDING AND COMPRESSION.

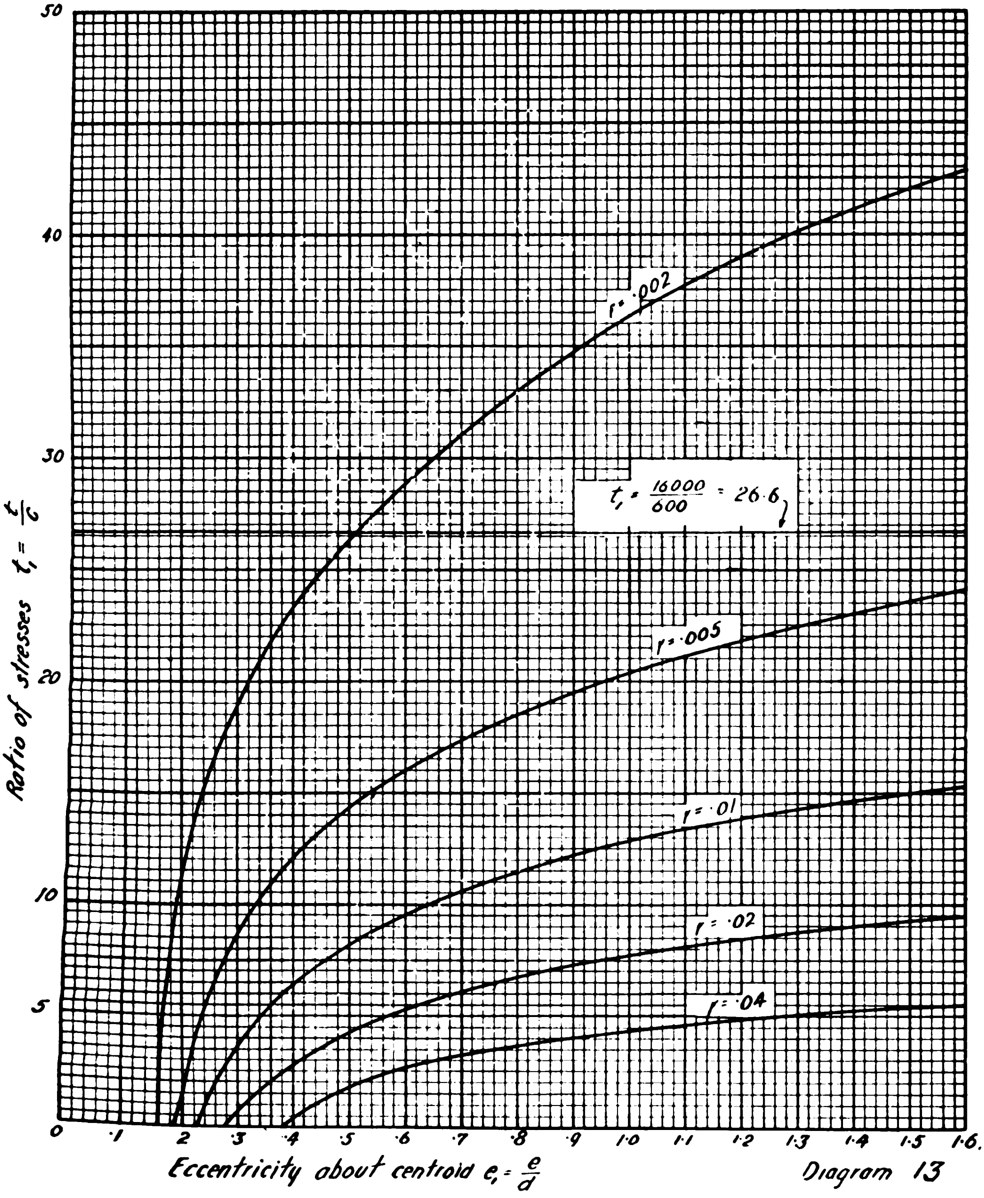


Diagram 13

As before, these have been calculated for various values of r and n and recorded in Table III and in Diagrams 8 to 13.

As before, we have divided the safe stresses, $= 16{,}000$ and $c = 600$, by values of $\frac{tbd}{P}$ and $\frac{cbd}{P}$ respectively, so as to arrive at safe values of $\frac{P}{bd}$ at which these stresses would occur, and by selecting the lower of the two values so obtained, have determined the limiting value of $\frac{P}{bd}$ at which *neither* of these safe stresses would be exceeded. These are recorded in Table IV and Diagram 14. As before, the higher (and, therefore, unrequired) value of $\frac{P}{bd}$ is generally not recorded.

TABLE IV.

Bending and Compression.

Safe Values of $\frac{P}{bd}$ for limiting stresses of $\begin{matrix} c = 600 \\ t = 16{,}000 \end{matrix}$

$r = {\cdot}002$			$r = {\cdot}005$			$r = {\cdot}01$			$r = {\cdot}02$			$r = {\cdot}04$		
e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600	e_1	$t =$ 16,000	$c =$ 600
·2	[377]	158	·2		261	·225		316	·27		323	·38		286
·3		119												
·4	[101]	88·4	·3		167	·3		222	·3		286	·4		272
·6	60·4	[66]	·4		130·5	·4		172	·4		222	·5		226
·8	42·8		·6		96·8	·6		126	·5		187·5	·6		195
1·0	33·3	[44·8]	·8		77·4	·8		101	·6		162	·8		154
1·2	27·15		1·0		64·9	1·0		84·5	·8		127·5	1·0		128
1·4	22·9		1·2		56·1	1·2		72·5	1·0		105	1·2		110
1·6	19·75		1·4		49·4	1·4		63·5	1·2		89·5	1·4		96
			1·6		44·4	1·6		56·6	1·4		78	1·6		85·7
									1·6		69			

An examination of Diagrams 8 to 14 brings out the following points :—

(Diag. 8).—The relationship between $e_1 + f_1$ and e_1 is a linear one, except at quite small eccentricities, but varies by about $\cdot 4d$ between $r = {\cdot}002$ and $r = {\cdot}04$. The lower end of these diagrams cease where they run into Case I (no tension).

(Diags. 9 and 10).—The difference between n_1 and g_1 is much less than in the case of bending and tension ; and, as in that case, diminishes as e_1 increases and eventually vanishes.

(Diags. 11 and 12).—The tensile and compressive stresses vary almost linearly with e_1 except at quite small eccentricities, much more so than with bending and tension (*cf.* Diagrams 4 and 5).

(Diag. 13).—Clearly all points on curves below the line $t_1 = 26{\cdot}6$ will be fully stressed in compression before they reach the limiting stress in tension. This evidently applies to steel ratios of ·005 and over (*i.e.*, all cases except very low steel ratios), up to limit of $e_1 = 1{\cdot}6$.

(Diag. 14).—The usefulness of this in design is obvious (or will be when it has been tried). For the reason stated in the last paragraph, only the lower curve contains a portion where steel stress limits the safe load.

Example I.—A reinforced beam with $d = 10$ in., $b = 6$ in., $A = 2$ ⅝-in. diam. rods $= {\cdot}614$ in.^{2} is subject to a moment of 60,000 lb. in. and a thrust of 6000 lbs.

The steel ratio is

$$r = \frac{{\cdot}614}{10 \times 6} = {\cdot}0102$$

and the eccentricity is

$$e = \frac{M}{P} = \frac{60{,}000}{6000} = 10 \text{ in.}$$

whence

$$e_1 = \frac{e}{d} = 1$$

Hence from Diagram 11,

$$\frac{cbd}{P} = 7{\cdot}1$$

whence

$$c = \frac{7{\cdot}1 \times 6000}{6 \times 10}$$

$$710 \text{ lbs./in.}^2$$

From Diagram 12,

$$\frac{tbd}{P} = 92$$

whence

$$t = \frac{92 \times 6000}{60 \times 10}$$

$$= 9200 \text{ lbs./in.}^2$$

The other quantities, such as n, g, f, $e + f$, etc., can, if required, be obtained by inspection from Diagrams 8 to 13.

EXAMPLE II.—A beam has to carry a direct thrust of 20,000 lbs. and a moment of 100,000 in. lbs. Select a suitable section for maximum stresses not to exceed 600 and 16,000.

Solution.—Take

$$d = 20 \text{ in.}$$

$$e = \frac{M}{P} = \frac{100{,}000}{20{,}000} = 5 \text{ in.}$$

Then

$$e_1 = \frac{e}{d} = \cdot25$$

Hence from Diagram 14, with

$$r = \cdot01, \quad \frac{P}{bd} = 270$$

$$b = \frac{P}{270d} = \frac{20{,}000}{270 \times 20}$$

$$= 3{\cdot}7 \text{ in.}$$

Area of steel

$$= \cdot01 \times 20 \times 3{\cdot}7 = \cdot74 \text{ in.}^2$$

Clearly alternative solutions with other depths and percentages can readily be obtained with ease from the diagrams.

CASE III: WHEN e_1 EXCEEDS 1·6.

For the sake of accuracy, the curves were limited in range to e_1 up to 1·6. Beyond this, the stresses may be calculated as for pure bending, and the stress of

$$\frac{P}{A + \dfrac{bn}{m}}$$

deducted from the tensile stress and $\dfrac{P}{Am + bn}$ added to the compressive stress.

The expression $A + \dfrac{bn}{m}$ is the equivalent area of the beam (steel + compressed concrete) expressed in steel units, and $Am + bn$ the same expressed in concrete units.

EXAMPLE III.—A beam with $d = 10$ in., $b = 6$ in., $A = 2$ ⅝-in. rods = ·614 in. has a thrust of 3000 lbs. and a moment of 48,000 in. lbs.

Calculate stresses:

$$e = \frac{M}{P} = \frac{48{,}000}{3000} = 16; \; e_1 = \frac{c}{d} = \frac{16}{10} = 1{\cdot}6.$$

This, then, is a borderline example between Cases II and III, and may be treated by either.

Under Case III:

$$r = \cdot0102$$

$$\therefore n_1 = \cdot42 \qquad n = 4{\cdot}2 \text{ in.}$$

$$a_1 = \cdot86 \qquad a = 8{\cdot}6 \text{ in.}$$

Total compression:

$$= \frac{M}{a} = \frac{48{,}000}{8{\cdot}6} = 5600 \text{ lbs.}$$

$$= nb\frac{c}{2}$$

$$= 4{\cdot}2 \times 6 \times \frac{c}{2} = 12{\cdot}6c,$$

whence

$$c = \frac{5600}{12{\cdot}6} = 445 \text{ lbs./in.}^2$$

$$t = \frac{5600}{\cdot614} = 9120 \text{ lbs./in.}^2$$

To allow for thrust, deduct from t

$$\frac{P}{\dfrac{bn}{m} + A} = \frac{3000}{\dfrac{6 \times 4{\cdot}2}{15} + \cdot614}$$

$$= 1305 \text{ lbs./in.}^2$$

and add to c

$$\frac{P}{Am + bn} = \frac{3000}{34{\cdot}4} = 87 \text{ lbs./in.}^2$$

leaving

$$t = 9120 - 1305 = 7815 \text{ lbs./in.}^2$$

and

$$c = 445 + 87 = 532 \text{ lbs./in.}^2$$

ACCURATE SOLUTION UNDER CASE II BY DIAGRAMS.

$$r = \cdot0102 \qquad e_1 = 1{\cdot}6$$

From Diagram 12:

$$\frac{tbd}{P} = 162 \qquad t = \frac{162 \times 3000}{6 \times 10}$$

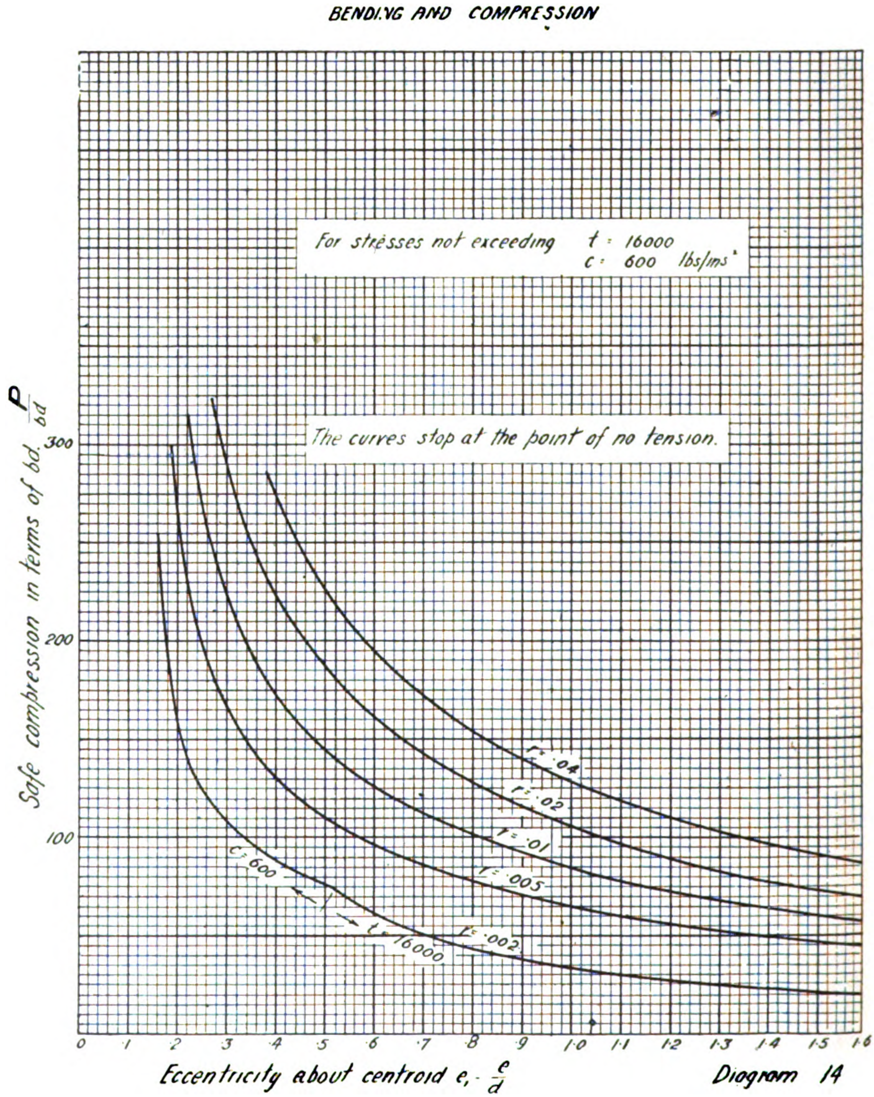
$$= 8100 \text{ lbs./in.}^2$$

From Diagram 11:

$$\frac{cbd}{P} = 10{\cdot}6 \qquad c = \frac{10{\cdot}6 \times 3000}{6 \times 10}$$

$$= 530 \text{ lbs./in.}^2$$

It will be seen that the approximate


BENDING AND COMPRESSION
For stresses not exceeding t = 16000
c = 600 lbs/ins²
The curves stop at the point of no tension.
r = ·04
r = ·02
r = ·01
r = ·005
r = ·002
c = 600
t = 16000
Safe compression in terms of bd. P/bd
300
200
100
0
·1
·2
·3
·4
·5
·6
·7
·8
·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6
Eccentricity about centroid e, - e/d
Diagram 14

solution under Case III is not badly out, and its accuracy increases with increasing value of e_1.

CASE IV: WHEN COMPRESSION REINFORCEMENT ALSO IS PROVIDED.

This follows the treatment as given under bending and tension, by calculating what increased breadth of beam *without* compression reinforcement would give the same strength to the compression side as the actual beam plus its compression reinforcement, and then examining the equivalent beam by our diagrams.

EXAMPLE IV.—Let us recalculate Example I with the addition of 2 ⅝-in. rods in compression, 1¼ in. from the edge, P = 6000 lbs. and M = 60,000 in lbs. as before. (See *Fig.* 3.)

From

$$r = \cdot 0102$$
$$e = 10 \text{ in.} \quad e_1 = 1$$

we have from Diagram 9:

$$n_1 = \cdot 54$$
$$n = 5\cdot 4 \text{ in.}$$

Total compression in concrete:

$$= nb\frac{c}{2} = 5\cdot 4 \times 6 \times \frac{c}{2}$$
$$= 16\cdot 2c$$

Additional compression in compression steel:

$$= A(m-1)c \times \frac{n - 1\tfrac{1}{4} \text{ in.}}{n}$$
$$= \cdot 614 \times 14 \times \frac{\cdot 415}{\cdot 54}c = 6\cdot 6c.$$

Hence the effect of compression steel is equivalent to increasing the breadth to

$$6 \times \frac{16\cdot 2 + 6\cdot 6}{16\cdot 2} = 8\cdot 45 \text{ in.}$$

r of the equivalent beam is

$$r = \frac{\cdot 614}{8\cdot 45 \times 10} = \cdot 0073$$
$$e_1 = 1 \text{ as before}$$

whence

$$n_1 = \cdot 5 \qquad n = 5 \text{ in.}$$

(from Diagram 9).

This agrees well enough with the trial value of $n = 5\cdot 4$ in. (unless great accuracy is required, when a second calculation of equivalent breadth may be made, as was done under bending and tension).

Then from Diagram 11:

$$\frac{cbd}{P} = 8\cdot 3$$

whence

$$c = \frac{8\cdot 3 \times 6000}{8\cdot 45 \times 10}$$
$$= 590 \text{ lbs./in.}^2$$

From Diagram 12:

$$\frac{tbd}{P} = 125$$

whence

$$t = \frac{125 \times 6000}{8\cdot 45 \times 10}$$
$$= 8880 \text{ lbs./in.}^2$$

It will be seen from Example I that the compression steel has reduced the concrete stress from 710 to 590, and the steel stress from 9200 to 8880.

CASE V: WHEN, INSTEAD OF M OR e BEING GIVEN, THE POSITION OF THE RESULTANT THRUST IS GIVEN.

In this case, the eccentricity can at once be found from Diagram 8, and the procedure is then as before. If $e_1 + f_1$ exceeds 2 and is off the Diagram, e may be taken as $(e + f) - (d - n)$, its correct value for pure bending, n being the depth of natural axis for pure bending corresponding to the particular steel ratio.

New Concrete Machinery.

We recently had an opportunity of seeing a demonstration of a series of concrete machines, invented by Mr. Carl Lyno, of Roskilde, Denmark, and embodying many novel and interesting features. The plant included a pipe-making machine, a brick-making machine, a block-making machine, and a mixer, the two last-mentioned being made for hand and power operation. A feature of all the power-driven machinery is that it is completely automatic.

The pipe-making machine (*Fig.* 1) produces from 140 to 150 pipes, 6 in. by 24 in., per eight-hour day, while longer pipes can also be made. The concrete is fed into the trough at the top, where it is further mixed by rods on a revolving axle so arranged that whilst being stirred the material is fed to the chute running from the materials trough to the mould. The rate of discharge is controlled by a door.

The mould is of steel, made in two vertical sections which can be easily taken apart and released from the finished pipe. This is placed on the circular platform, and a steel core, which can be reduced in diameter to release the finished pipe, is set inside it. The machine is then started, and until the pipe is finished the whole operation is automatic. Concrete is fed down the chute at a pre-arranged rate, the tampers operate striking 325 blows each a minute, and the platform rotates and carries the mould with it so that every part of the pipe is tamped as the concrete is poured.

The tampers are steel rods which work independently of each other, and are so arranged that as the concrete gets higher

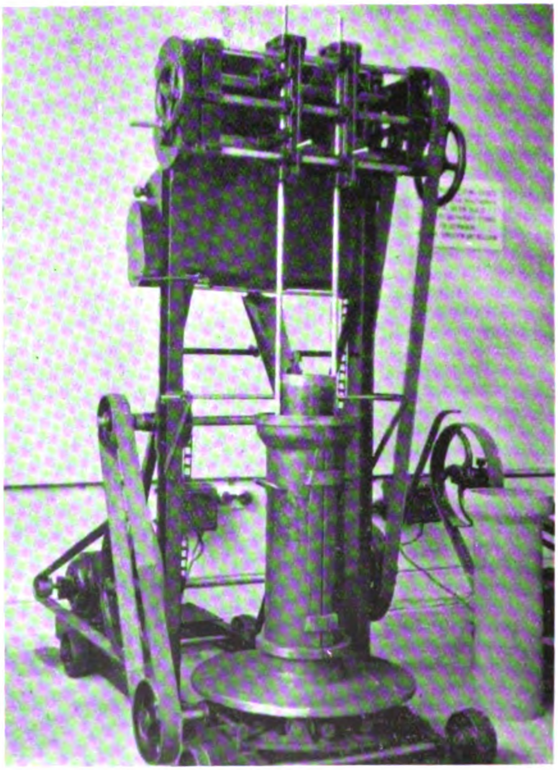


Fig. 1.—Pipe-Making Machine.

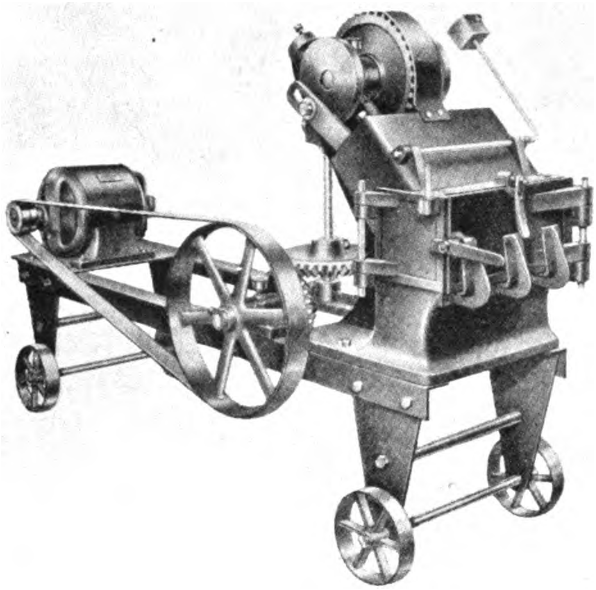


Fig. 3.—Block-Making Machine.

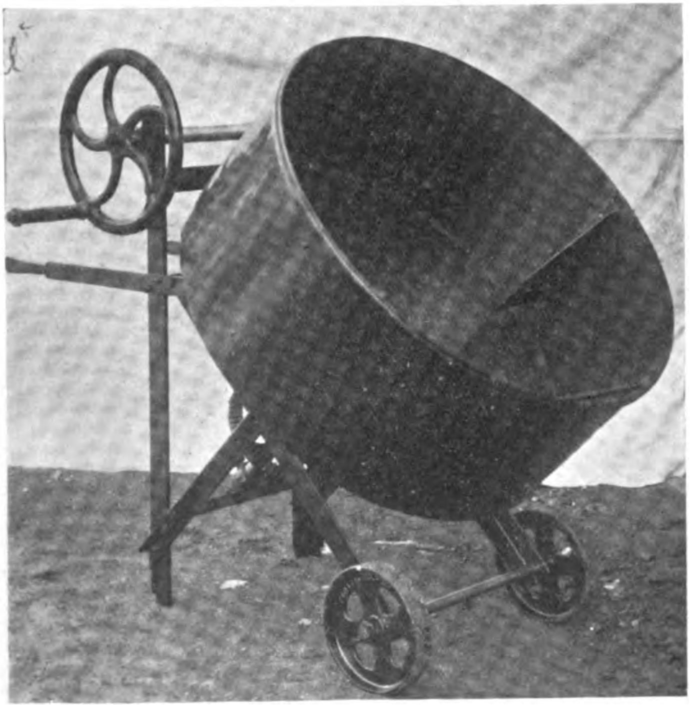


Fig. 4.—Mixer.

in the mould the tampers are also raised so that they strike blows of uniform weight throughout the height of the pipe. The power required is 1 h.p., and pipes of all usual dimensions from 3 in. upwards can be made.

The brick-making machine (*Fig.* 2) is claimed to produce 800 bricks per hour under average working conditions. The cycle of operations in the manufacture of a brick as the circular table rotates is as follows: The mould-box, with a pallet in the bottom, is filled. As it passes a point a little farther along it is vibrated by passing over a joggle arrangement. Next it reaches an incline which lifts the mould-box and presses it against a metal plate on the top of the table to consolidate it; the plate moves with the brick for a short distance in order to prevent waste of power by friction. Continuing along this incline, the mould box is raised above the level of the table. The pallet and brick are then removed, and another pallet placed in the mould-box ready to go through the same cycle of operations. Thus four bricks are made at every revolution of the table: while one mould-box is being filled, another is being vibrated, another is receiving pressure, and another is being removed from the machine. The machine can be set to operate at any desired speed to suit the output required or the speed of the operatives. A $1\frac{1}{2}$ h.p. engine is sufficient to operate the machine.

The block-making machine (*Fig.* 3) is designed to make a special L-shape block used in a new system of wall construction patented by the inventor. As with the brick machine, the output is governed by the machine, which can be set to produce any desired number from one to four a minute. The front and side of the mould-box are closed and concrete

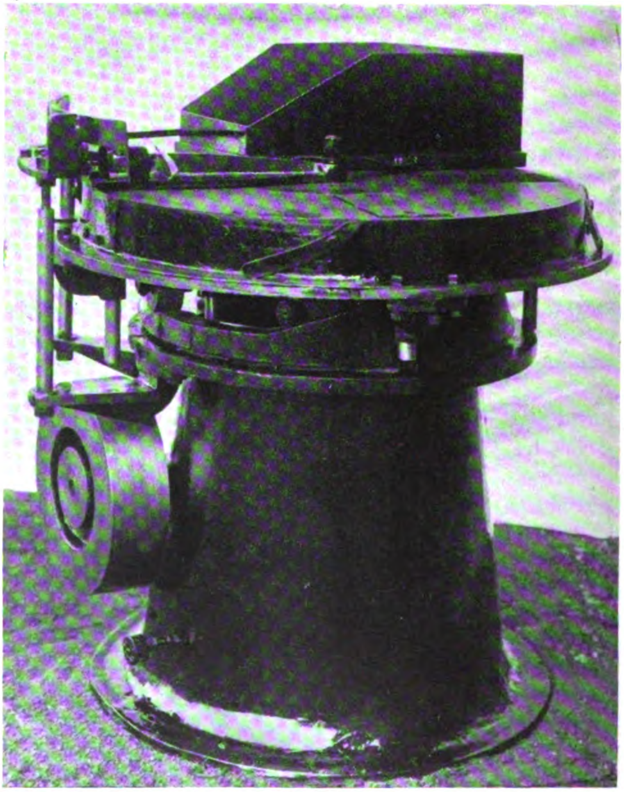


Fig 2.—Brick-Making Machine.

is poured in. The mould-box is then closed, and the electric motor or petrol engine started. This applies pressure diagonally down into the mould-box so as to consolidate the L-shape block throughout. After applying pressure the consolidator is automatically drawn up to its first position, the mould-box is opened, the block removed, a fresh pallet and another charge of concrete inserted and the doors of the mould closed again before the consolidator again commences its downward stroke, the rate of motion of the consolidator being governed according to the time taken to carry out these operations. Power required, 1½ h.p. The same type of machine is made for hand-operation.

As will be seen, the mixer is of the open-pan type containing two blades. Ten revolutions of the drum are sufficient to give a thorough mix. The mixing is mostly done while the materials are traveling from the top to the bottom of the inclined pan-bottom, and in order that a steeper angle may be used for stiffer mixes the pan is so mounted that its degree of inclination can be varied. The machine has a batch capacity of 4 cu. ft., and requires 1 h.p. to drive; it is also made in other sizes.

This machine is also made for hand-operation with a batch capacity of 2½ cu. ft. The hand-mixer (*Fig.* 4) is so made that it can be wheeled about and along plank tracks, so that the concrete can be discharged direct where required without the double handling entailed if it has to be transferred to a wheelbarrow. Discharge is through a door in the side of the pan.

All these machines are mounted on wheels so as to be readily portable, and pains have been taken to see that they shall be easy to keep clean.

We understand that the inventor, whose agent in this country is Mr. H. Lauratzen, of 18–21, Charterhouse Square, E.C., is desirous of disposing of the patent rights of the machines in this country.

All-Concrete Road in Middlesex.

[Our illustration is of the Colnbrook By-Pass Road, recently completed for the Middlesex County Council under the direction of Mr. Alfred Dryland, M.Inst.C.E., the County Surveyor. The road is 8 in. thick, reinforced with B.R.C. fabric.]

London County Council Regulations for Reinforced Concrete.

Extension to Include Conversion of Buildings Partly or Wholly of Reinforced Concrete.

On June 10 and 11, a Select Committee of the House of Lords, consisting of Lords Crawshaw, Glenarthur, Redesdale (Chairman), Analy, and Lawrence, heard the petitions of the Institution of Civil Engineers, the Royal Institute of British Architects, the Surveyors' Institution, and the Institution of Structural Engineers against the amendments to the London Building Acts contained in the London County Council (General Powers) Bill, 1926.

The amendment deals with the regulations for reinforced concrete buildings and is as follows:

The Proposed Amendment.

"**5.** (1) The provisions of section 23[*] (Power to make regulations as to use of reinforced concrete of the London County Council (General Powers) Act 1909 (in this Part of this Act referred to as "the Act of 1909") shall extend to enable the Council, subject to the provisions of that section, to make and enforce regulations with respect to the conversion of any building or part of a building constructed wholly or partly of reinforced concrete so that such building or part of a building when converted would not be in conformity with the regulations applying to such construction.

"(2) (*a*) In order to facilitate the erection of any particular building or part of a building intended to be constructed wholly or partly of reinforced concrete, or the conversion of any particular building or part of a building so constructed, the Council may in relation to that building or part of a building modify or waive, upon and subject to such terms and conditions as they think fit, any of the requirements of the regulations made under the said section 23 as extended by this section.

"(*b*) Any person failing to comply with any term or condition attached to any such modification or waiver as aforesaid shall be liable on summary conviction to a penalty not exceeding twenty pounds, and to a further penalty not exceeding twenty pounds for each day on which the offence continues after conviction thereof.

"(3) For the purposes of this section a building or part of a building shall be deemed to be converted not only when it is structurally altered, but also if and whenever any change is made in the purposes for which the building or part of a building is used.

"(4) The provisions of this section and any regulations made thereunder and for the time being in force shall be deemed to form part of Part VI of the London Building Act, 1894.

"**6.** (1) So much of sub-section (5) of section 23 of the Act of 1909 as requires the publication in the 'London Gazette' of regulations made under that section shall cease to have effect.

"(2) When any regulations made under the said section 23 as extended by this Part of this Act have been allowed and are open to public inspection and copies thereof can be obtained in accordance with the provisions of that section as so extended notice thereof shall be published by the Council in the 'London Gazette.'"

Report of the Ministry of Health.

The Ministry of Health submitted the following report on the proposed amendment:

"(1) By section 23 of the London County Council (General Powers) Act, 1909, the Council obtained power to make regulations controlling reinforced concrete construction. For practical purposes these regulations are tantamount to by-laws. Some years were spent in collating similar regulations in force in other countries, and, after exhaustive discussion with the Local Government Board, the Council's regulations were confirmed by the Board and came into operation in 1915.

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[*] Section 23 of the L.C.C. (General Powers) Act, 1909, contains the following:

"23.—(1) The Council may make regulations with respect to the construction of buildings wholly or partly of reinforced concrete, and with respect to the use of reinforced concrete in such construction, and for the purpose of framing such regulations may carry out such investigations and make such tests as they may deem necessary. . . .

"(4) The Council shall give to the Surveyors' Institution, the Institution of Civil Engineers, the Royal Institute of British Architects, and the Concrete Institute[1] notice of their intention to apply to the Local Government Board for allowance of any regulations made under this section."

[1] Now the Institution of Structural Engineers.

"(2) Even while the regulations were under consideration it was realised that the authorising section was not in all respects satisfactory, and it was suggested to the Council that opportunity should be found, when possible, to make some amendments of a minor character. There are amendments of this kind in Clauses 5 (1) and 6 of this Bill.

"(3) It is, however, necessary to take the strongest exception to Sub-clause (2) of Clause 5. The existing Act requires not only that regulations made by the Council shall be subject to the confirmation of the Minister, but also that he shall not confirm them until after they have been advertised and deposited for public inspection and have been communicated to four professional bodies named in the Act of 1909. By Sub-clause (2) it is proposed to take power in particular cases to waive or modify the requirements of the regulations upon such terms and conditions as the Council think fit.

"The Ministry are aware that there are precedents for this proposal in section 164 (2) of the London Building Act, 1894, and in section 5 of the London County Council (General Powers) Act, 1923. The first of these sections was enacted many years ago: it empowers the Council to make various by-laws (mostly upon matters which are also dealt with in the Act itself), but only one such series of by-laws—viz. as to lamps overhanging the footway—has been made. The second relates to the Council's statutory provisions as to steel-frame buildings: and these, being in an Act of Parliament, obviously cannot be amended with the same facility as by-laws or regulations. Indeed, where building is controlled by direct statutory provision a power of waiver, *ad hoc*, may be the only way to avoid hardship. The Ministry submit, however, that the principle should not be further extended so to apply to provisions for the amendment of which machinery exists.

"It is submitted that it is wrong in principle that regulations, which cannot come into force until after the special procedure laid down by Parliament has been followed, should be waived afterwards at the pleasure of the enacting local authority. It is to be presumed that Parliament considered, in relation to these regulations (as it has for nearly a century considered in relation to the by-laws of local authorities), that provisions which are to be enforceable against the individual by penalties should go through certain formalities, aimed primarily at full publicity. The amendment of the law proposed in this sub-clause would enable the Council at their pleasure to discriminate between one form of construction and another, the products of one manufacturer and those of another, and the proposals of one building owner and those of another.

"It is agreed that the existing procedure may be unduly dilatory where it is desired to experiment with methods of construction which were not foreseen when the regulations were framed, or to assent to some departure in exceptional cases. This contingency was, however, foreseen by the Departmental Committee on Building By-laws (on which the associations representing provincial authorities and the Institution of Municipal and County Engineers were directly represented). Speaking of the provinces, that Committee emphatically negatived the suggestion, made to them in evidence, that local authorities should have a discretionary power to depart from local by-laws in particular or exceptional cases, however convenient this might be in those cases. They took the view that where exceptional cases had to be met which did not call for an amendment of the by-laws (or regulations) of general application, the exception should be met by means of a special by-law, subjected to the same publicity as the original by-law. This procedure is constantly followed by provincial local authorities who desire (for example) themselves to erect some building of exceptional type which was not foreseen when they made their by-laws.

"(4) Under the provincial system, laid down in the Public Health Act, 1875, an amending by-law of this character need not take more than about six weeks from its inception to its confirmation. The principal item of delay is the statutory requirement of a month's advertisement.

It is not disputed that the requirements, as to notice in the Press and to the professional bodies, fixed in the County Council's Act of 1909, are inconvenient, and, to meet cases where it is desired to make an amending regulation *ad hoc*, no objection need be raised to any reasonable amendment of their Act of 1909 so as to shorten the period of two months there fixed. A conference took place in October last between officers of the Ministry and of the Council, when it was stated that the Minister would welcome a provision empowering the Council to make amending regulations more quickly—either for general purposes or for the purposes of particular structures which it might be desirable to approve as a matter of urgency.

" A clause was suggested informally at that time for the consideration of the County Council as a basis of discussion. The scheme of the clause was to enable the County Council to propose, and the Minister to allow, amending regulations required as a matter of urgency, and to prescribe in relation to them a shortened procedure in lieu of that provided for in section 23 of the Act of 1909.

" If the Committee concur in the principles stated in this report the Ministry will be prepared to agree a clause with the Council for submission to the Committee. So far as the Ministry are concerned they are prepared to agree to any amendment which recognises the principle on which Parliament has long insisted : that regulations of this type, enforceable against individuals by penalties, shall not come into force or be varied without some form of confirmation, and, above all, the basic principle of publicity.

" (5) A further point arises on subclause (4) of clause 5. Under that subclause not merely the section itself, but any regulations made under it are to be deemed to form part of Part VI of the London Building Act, 1894. This applies to the main regulations now in force by section 24 of the Act of 1909, but the provision is quite exceptional in regard to by-law matters. By-laws made by local authorities can be challenged in the Courts on the ground that they are *ultra vires* or unreasonable, notwithstanding that they have been confirmed by a Minister of the Crown. The Committee may take the view that the position should be the same with regard to these regulations, and that in connection with the further powers sought by the Bill the existing section 24 of the Act of 1909 should be amended and sub-clause (4) of the present clause omitted.

" (6) Moreover, the fact that the regulations would form part of the main Act of 1894 would raise a doubt whether the regulations once made could be altered otherwise than by an Act of Parliament.

" If the Committee consider that the principle of sub-clause (4) and of section 24 of the Act of 1909 should be maintained (i.e. that the regulations once made should not be challengeable in the Courts) it is submitted that at any rate it should be made clear that this will not prevent the regulations from being altered from time to time by regulations similarly made and allowed. This might be done by providing that, notwithstanding section 24 of the Act of 1909 and sub-clause (4) of the present clause, section 32 of the Interpretation Act, 1889, shall apply to the regulations. This section provides, by sub-section (3), as follows :

" ' Where an Act passed after the commencement of this Act confers a power to make any rules, regulations or by-laws the power shall, unless the contrary intention appears, be construed as including a power, exercisable in the like manner and subject to the like consent and conditions, if any, to rescind, revoke, amend, or vary the rules, regulations, or by-laws.' "

The Opposing Petitions.

The petitions of the four Institutions were all on the same lines, and contained the following :

" 3. By Section 23 of the London County Council (General Powers) Act 1909, which the Bill seeks to amend, your petitioners have special rights hereinafter mentioned as representative of the public, and their representative character is also recognised by the London Building Act 1894 under which your petitioners appoint a member of the Tribunal of Appeal under that Act whereunder your petitioners are also otherwise recognised by Parliament. Your petitioners accordingly claim to represent not only the interests of the members of their Institute but also the rights and interests of owners, lessees, and occupiers of property in London.

" 4. Your petitioners allege that the said interests are prejudicially affected by the Bill, and they object thereto for the reasons hereinafter stated amongst others.

"6. By Clause 5 of the Bill it is sought to extend the provisions of Section 23 of the London County Council (General Powers) Act 1909 so as to enable the Council to make and enforce regulations with respect to the conversion of any building or part of a building constructed wholly or partly of reinforced concrete.

"7. The said Clause further seeks to empower the Council to modify or waive, on such terms as they think fit, any requirements of any regulations made by them under the said Section 23 of the Act of 1909 as proposed to be extended by the Clause, and to impose a penalty of not exceeding £20 a day for failure to comply with any terms attached to any such modification or waiver.

"8. The said Clause further seeks to provide that for the purposes of the proposed legislation a building or part of a building shall be deemed to be converted not only when it is structurally altered but also if and when any change is made for the purposes for which such building or part of a building is used.

"9. When the Council by the Bill for their Act of 1909 put before Parliament proposals to enable the Council to make regulations as to the use of reinforced concrete, which proposals resulted in the passing of the said Section 23, your petitioners petitioned against the Bill and appeared before the Committee of the House of Commons, to which the same was referred, and also petitioned against the Bill in the House of Lords, and various modifications of the proposals then made by the Council were made by Parliament in the said Bill at the instance of your petitioners and others, and it was provided by the said Section 23 that no regulations made by the Council thereunder should have any effect until they had been confirmed at a meeting of the Council subsequent to that at which they were made and should have been allowed by the Local Government Board (now the Minister of Health). The said Section further provides that the Council should give to your petitioners and to certain other professional bodies mentioned therein notice of their intention to apply to the said Local Government Board (now the said Minister) for allowance of any regulations made under the said Section.

"10. The provisions of the Bill, while seeking to empower the Council to make additional regulations to those permitted by the said Section 23 of the Act of 1909 with reference to the use of reinforced concrete, entirely fail to require the Council to give notice to your petitioners of their application for confirmation of any regulations made under such proposed extended powers such as they now have to give to your petitioners and others in respect of application for confirmation of similar regulations under their existing powers.

"11. Your petitioners submit that if Parliament has thought it desirable and in the public interest that your petitioners should have an opportunity of making representations to the confirming authority in respect of regulations submitted for confirmation under the law as now existing, no possible ground exists for suggesting that it is not equally in the public interest and proper that your petitioners should have a similar right of making representations to the confirming authority in respect of regulations made in relation to similar matters under the extended powers which the Council now seek by the Bill.

"12. The proposals of Clause 5 are unsatisfactory. It is clear to bodies such as your petitioners, who have had to consider the matter in its technical aspect, that Section 23 of the Act of 1909 does not accurately describe the character of the buildings to which the regulations referred to in that Section are intended to apply. That this is the case is, as your petitioners submit, made more plain when reference is had to Section 22, the preceding Section of the Act of 1909.

"13. Section 23 of the Act of 1909 is somewhat loosely worded, and in your petitioners' view it would have been more accurate if that Section, instead of referring to a building wholly or partly of reinforced concrete, had referred to a building having a skeleton framework which is wholly or partly of reinforced concrete. Section 22 had already dealt with buildings having a skeleton framework of metal.

"14. It will accordingly be seen that the literal wording of Section 23 would allow the Council to make regulations which would apply *in toto* to a building which might otherwise be of steel skeleton frame construction or even of ordinary brick work merely because the flooring of the building or even one passage or, to take a very extreme example, a lintel over a door, was of reinforced concrete construction.

"15. Your petitioners submit it is extremely undesirable that there should be any extension granted by Parliament of the powers conferred upon the Council to make regulations by Section 23 of the Act of 1909 unless the power to make those regulations is clearly confined to the matters to which, as your petitioners believe, all professional bodies concerned would agree that they were intended to apply.

"16. The effect of the regulations which have been at present made by the Council has undoubtedly been to hamper the adoption of reinforced concrete construction, and it is, your petitioners submit, very undesirable, having regard to the housing difficulties which exist to-day, that there should be any power to make regulations which unnecessarily have this effect.

"17. Under the said Section 23 as it stands, and still more so under the Section as it is proposed to be amended by the Bill, the Council could make regulations which would have this deterrent effect on the adoption of this form of construction to a greater degree than the regulations which they have already made.

"18. The matter is, of course, one of extreme technicality and your petitioners appreciate that the confirming body, now the Minister of Health, may even, in spite of the representations of your petitioners and other professional bodies, feel a difficulty in declining to sanction regulations which by reason of the incorrect wording, as your petitioners consider, of the Section, the Council have power to make, even though it may be shown that such regulations are unnecessary and even harmful in their operation.

"19. For these reasons your petitioners submit that it is of public importance, now that a proposal arises to amend the said Section 23, that Parliament should consider whether that Section as framed is desirable in the public interest or whether the wording of it does not apply to classes of construction to which it is not suitable or properly applicable and that Parliament should deal with the matter accordingly."

The Proceedings.

The Hon. Evan Charteris, K.C., Mr. Rowand Harker, K.C., and Mr. F. N. Keen appeared for the London County Council, and Mr. Craig Henderson, K.C., for the four petitioning Institutions.

In opening the case for the Council Mr. Charteris said the first opposition was directed against Clause 5 of the Bill which dealt with certain amendments and new proposals connected with building operations and the Building Acts. He ought, perhaps, to explain the position of the Council with regard to building operations in London. The Council was the authority for seeing that the Building Acts were enforced in the Metropolitan area. The regulations and local enactments were contained in a number of statutes up to 1894, when the Council introduced a Bill which consolidated the previous enactments and also amended the building laws and brought them as far as possible up to date. But in the developments of building practice it was impossible to stand still, and from time to time legislation had to be initiated in order that the laws connected with building could be brought up to date and into line with the progress of engineering developments. In 1909 steel-frame buildings had become so advanced that legislation was found to be necessary, and at that time reinforced concrete was also coming into great use. While it was thought necessary to legislate for steel-frame buildings, therefore, it was also thought advisable to make provision for the development anticipated in the use of reinforced concrete. This legislation, of course, had as its primary object the safety of the public, but the Council had also to see that safety of the public was as far as possible reconciled with the progress of building science.

Bearing these principles in mind, a section to enable the Council to make regulations relating to reinforced concrete was included in the 1909 Act. But the framing of the regulations was a highly technical matter, and it was not until 1915 that they were drafted in their final form and received the approval of the Local Government Board. As was anticipated, these regulations had been found to be too hard-and-fast, and yet they had to be followed without deviation of any kind. During the years that had passed since the regulations were framed many applications had been made to the Council for a relaxation of the rules, relaxations which could have been granted with perfect safety so far as structural soundness was concerned, but which the Council was unable to grant, with the result that building operations had been unnecessarily impeded at a time when every possible facility should be given to building operations, and progress in design was also impeded. The regulations unnecessarily restricted the form architects and engineers could give to their buildings, and it was one of the objects of the Bill to give the Council power to relax and waive the present regulations in order to permit greater facilities in the design and construction of this new material. It was satisfactory to note that not a single body representing property owners or builders objected to the proposals of the Council. The only objection came from the technical societies, and they not so much objected to the immediate proposals contained in Clause 5 as suggested that the Committee should take the opportunity of amending an Act passed in 1909. It had to be noted that the Act of 1909 made no provision for the case of a building of reinforced concrete being constructed for one purpose and converted for another user; e.g., if a reinforced concrete building were erected for domestic purposes and later converted to a warehouse it would come under none of the existing regulations.

But it was desirable in the interest of the public safety that such a building should come under the regulations in its converted form, and in making provision for it, as was done in Section 5, the precedent set in the Act of 1909, in the case of steel-frame structures, was strictly followed. The object of Clause 5 was this: It was intended to bring within the regulations a building of reinforced concrete which, by being converted, had been placed outside the regulations, but which had it been a new building specially erected for its new purpose would have been within the regulations. Under the Act of 1894, the Council had power to deal with other types of buildings when they were converted from one user to another, but they had no power in connection with converted reinforced concrete buildings. He understood neither the Ministry of Health nor the Institutions raised any objection to this part of the Section. Sub-section 2 of Clause 5 would give the Council power they had felt the need of ever since 1915. It had been found that in a considerable number of cases the regulations might have been waived or modified, with perfect safety to the public, but owing to the form the regulations had taken the Council had no power to waive or modify them. The Council now sought the necessary power which would enable it to waive or modify the regulations in cases where its technical advisers advised the Council that it would be quite safe to do so.

The process of waiving or modifying a regulation was as follows: The person who wanted a regulation modified applied to the Council, and the Council deputed the hearing and investigation of the claim to the Building Committee, but this procedure was not at present applicable in the case of reinforced concrete buildings. He might point out that the technical advisers of the Council had probably a larger volume of technical knowledge and experience to draw upon than any similar body in the world. It was not the practice of the Building Committee to report to the Council on these matters, but if it were thought desirable that it should do so in the case of reinforced concrete buildings the Council had no objection whatever to such reports being made, although this would be specially distinguishing reinforced concrete from steel.

The real objection to the proposal came from the Ministry of Health, who while they made objections which they were fairly entitled to make, also appeared to be advocates asking the Committee to take a particular point of view. The objection of the Ministry was this: They said whatever the regulations might be, whatever scientific developments might take place, and whatever the progress in building in the future might be, regulations once made and sanctioned by the Minister of Health were to remain rigidly in force in their original form without waiver or modification by the Council who originally made them. That was a position that had to be dealt with, and the best way to deal with it appeared to be to examine what Parliament had done in the past in connection with similar provisions with which the Council was concerned. Here Counsel gave instances in other directions and in connection with the London Building Acts in which the Council was given absolute discretion to waive or modify regulations as it thought fit, including the regulations relating to steel-frame construction in the Act of 1909.

Continuing, Counsel said all the Council was doing was asking the Committee to give it the same power of discretion to waive or modify regulations for reinforced concrete that Parliament had given it in connection with steel-frame buildings and in other directions. The report of the Ministry (*see* p. 526) did not give the Council credit for much judgment in such matters, and when the report mentioned regulations being modified at the Council's "pleasure" surely it would have been better to have said at the Council's "discretion."

In regard to the petitions of the four Institutions, he could not help thinking they were under a misapprehension, because any regulations drawn up as a result of the Bill would be subject to the Act of 1909, in Section 23 of which it was enjoined on the Council that it must notify those Institutions of its intention to obtain the sanction of the Minister of Health to the regulations. That process would also apply to the regulations the Council was now seeking power to make; whatever rights the Institutions had under the 1909 Act were preserved to them. The purport of the objection was to ask the Committee to say that Parliament was wrong in 1909, and that when Parliament passed Section 23 enabling the Council to make regulations it ought to have worded the Section in a different form. The Committee was now asked to revert to the legislation of 1909, which was the derivative source of the Council's power, and to alter the enactment. The Bill did not seek to alter the law; all it sought to do was to make the law of 1909 applicable to the making of regulations in the future. As to the contention in Section 14 of the Petition, he thought the petitioners had overlooked Section 27 of the 1909 Act, which would exempt from the regulations a person who inserted a reinforced concrete lintel in a brick building. Section 27 of the Act of 1909 was specially designed to deal with such a case. As to the suggestion in Section 15 of the petition that the Council was seeking to extend its powers, the fact was that it was seeking to make new regulations which would be subject to the same limitations as Parliament imposed in 1909. The arguments that had influenced the Council in seeking power to modify and waive the regulations when they were made were exactly those suggested in Section 16 of the petition. As to Section 17, the object of the regulations was not to hamper building operations, and that had not been the effect of regulations in the past. The most that could be said against them was that in certain cases it had been found desirable to modify them in order to allow new ideas to be used. Beyond that it would be quite a misrepresentation to say that anything done by the Council in other regulations had had any tendency to frustrate or hamper or arrest the development of reinforced concrete. Section 18 was another indication that the petitioners desired an alteration of Section 23 of the Act of 1909.

Mr. R. I. TASKER, M.P., J.P. (Chairman of the Building Acts Committee of the London County Council), was then called, and in evidence said the Building Acts Committee had had under consideration the question of revising the regulations in order to keep in touch with the most recent practice and to facilitate the erection of buildings of reinforced concrete. The undoubted improvement in the quality of materials and the development of scientific construction made it all the more desirable that the regulations should not be administered with rigidity, but should be more or less elastic. For example, the best Portland cements of to-day had double the strength of the best cements made in this country when the regulations were made more than ten years ago. Also, one result of the war had been to emphasise the necessity for economical construction, and in steel-framed buildings the Building Acts Committee had accepted the principle that the requirements as regarded floor loads might be reduced in special cases. The same consideration should be given to special cases in reinforced concrete construction. The Building Acts Committee was of opinion that one direction in which the erection of such buildings might be facilitated would be by enabling the Council to waive or modify any of the requirements of the regulations in particular cases. He would have no objection to cases of waiver or modification under Clause 5 of the Bill being reported to the Council. The number of cases of waiver in respect of steel-framed buildings dealt with by the Building Acts Committee in 1925 was 75, and in 1924, 41. The number of cases of dispensation of the by-laws under Section 164 in 1925 was 118, and in 1924, 145. The Committee were advised that this dispensing power could not be dealt with in the regulations controlling reinforced concrete buildings without further statutory authority, and the Council resolved on February 24, 1925, that application be made to Parliament for powers to enable the Council to waive or modify, subject to such terms and conditions as it might think fit, any of the regulations made under Section 23 of the Act of 1909. This power was now sought in Clause 5, Sub-clause (2) of the Bill. The proposed provision had been objected to by the Ministry of Health on the ground that as the approval of the Ministry was necessary to the regulations, the Council ought not to have power to waive the regulations except with the consent of the Minister. The Ministry proposed that the Council should have power to make, subject to the approval of the Minister, new or revised regulations to meet cases of new methods of construction or special circumstances, with power to the Minister to vary the procedure. The Building Acts Committee was not able to adopt this suggestion, as it was considered that the framing of a regulation to meet each case would be impracticable, as the circumstances of individual cases might be so different as to be inapplicable in other cases. Having regard to the existing law in which Parliament had granted to the Council discretionary power in respect of direct enactments and by-laws, it was not unreasonable to ask that a power of waiver should be given as to the regulations for reinforced concrete buildings. Clause 5 of the Bill also dealt with the conversion of buildings of reinforced concrete construction. The Building Acts Committee was advised that cases of the conversion of such buildings, either by structural alteration or change of user, so as to render them not in conformity with the regulations, could not be dealt with under the Council's existing powers. With regard to the power of waiver sought by the Council, to which objection was taken by the Ministry, he drew attention to the model by-laws, series IV, as to new streets and buildings for boroughs and urban districts. These model by-laws provided as to reinforced concrete construction that "a wall built of cement concrete or of reinforced concrete shall be of such thickness as shall be necessary to secure due stability." The effect of this by-law was that complete discretion was vested in the borough or urban district, who might make whatever requirements they considered necessary to secure stability. The Ministry was, however, unwilling that a discretionary power of waiver should be conferred on the Council, although the Council had a staff which, in addition to preparing the existing regulations as to this form of construction which formed the first code promulgated in this country, was continuously engaged in dealing with applications as to special and temporary buildings under Sections 82, 83 and 203 of the London Building Act, 1894. Yet the Ministry denied to the Council the discretion which was conceded to an unlimited degree to an urban district council. The Council had repeated applications from engineers, architects and builders for permission to use new materials, but were unable to grant such permission because it had no power to do so. Architects were continually asking for permission to design buildings in accordance with modern practice, but unfortunately the Council was unable to permit them to do so in many cases, whereas such buildings could be erected without hindrance 100 yards outside the Council's area.

Mr. Henderson: The Act of 1894 governs the external walls of a building only, while the construction of the interior work is under the supervision of the District Surveyors. There is a further protection under the Act of 1894 that the building owner has a right of appeal against the decision of the Building Acts Committee to the London Tribunal of Appeal. Because the Act of 1894 did not deal with steel-frame buildings, which were a later development, the Act of 1909 was framed to cover this class of construction, and in this Act a right of appeal was given against the decision of the Building Acts Committee in respect of applications for waiver or modification of the regulations. But the right of appeal was to be refused now in the case of applications for modification under the reinforced concrete regulations. Why should there not be the same right of appeal against the Council in the case of a reinforced concrete building as existed in the case of steel-frame buildings ?

Mr. Tasker : Theoretically there can be no objection, but in practice there were very few cases submitted to the Tribunal of Appeal. There had been only four such appeals in the past five years.

Mr. Henderson : Are there not many buildings in London under the 1894 Act built partly of reinforced concrete, in the sense that they have reinforced concrete floors, and if any alteration were made to such buildings would they come under the regulations ?—Alterations to the structure would, but not alterations of user.

Mr. Henderson : My point is that under the principal Act of 1894 the Council already has power over the external structure, and the District Surveyor's consent has to be obtained to internal alterations. Therefore there is already ample authority, and the right to appeal, but under the Bill you are proposing to extend your powers. Have you any objection to the right of appeal being maintained under this new Bill ?—No.

Sir OWEN WILLIAMS, K.B.E., the next witness called for the promoters, said before the buildings at Wembley could be controlled by any building authority it was necessary for the Wembley Urban District Council to obtain the approval of the Ministry of Health to additional by-laws empowering them to control buildings of reinforced concrete construction. The effect of these by-laws was to leave the entire regulation of the construction of these large buildings, which were known to be liable to intensive use, in the hands of the Urban District Council. He was of the opinion that the conversion of a building, for purposes of proper control, should be taken to include, in addition to visual structural alterations, a change of user. For instance, if a building were originally designed with entrances to accommodate lorries 8 ft. high, structural alterations were obviously necessary if the height was increased to 12 ft. If, also, the 8-ft. lorry weighed 1 ton and the floor was designed for this, it would be equally necessary to reconsider the floor construction if the 12-ft. lorry weighed 2 tons. Regulations of this kind were primarily for the protection of the public, but it was at the same time of importance to ensure that the existence of the regulations should not unduly handicap " movement." Design was based on compliance with conditions. Conditions never repeated ; therefore design never repeated and was always in a state of " movement," even distinct from progress. It was in " movement " that designing skill was exercised. Regulations of this kind recorded the experience of the past, and if they attempted to fix the future, that was, the day-by-day work of the designer, they would have the effect of removing all incentive to design, which would be degraded to a mathematical routine. All such regulations should therefore allow for " movement " and progress, particularly in regard to a method of construction that was comparatively new. The existing regulations did not permit any departure from the requirements contained therein. Such rigidity was a great hardship, and could only have the effect of hampering building. The proposed waiver would undoubtedly facilitate building. The revision of the regulations from time to time would not meet this point, as there were variations in design which were peculiar and specific and not of general application, and if relief were only to be found by the amendment of the regulations there would be a serious handicap, as the delay would not only render the adoption of the idea impossible in the individual case but would actually discourage the inception of new ideas in the area controlled by regulations which were not quickly adaptable to special conditions. Witness had experienced numerous examples in which the power of waiver would be of value if it were desired to adopt the same ideas in London. For example, columns designed under the London regulations gave a size which in exceptional circumstances was a handicap to vision. Columns of the slenderness used at Wembley would under the London regulations not be able to carry any load. The columns in question, if subject to the regulations, would come under the definition for reinforced concrete columns, whilst in actual calculation they were structural steel columns although they would not come under the structural steel regulations. As regarded the question of applying regulations dealing with reinforced concrete construction to the external portion of a building and not to the internal portion, he was of opinion that the external and internal structure formed an entity, and it was impracticable to consider them apart.

Mr. G. Topham Forrest, F.R.I.B.A. (Architect to the L.C.C.), was then called. Examined by Mr. Charteris, he said the reason for seeking power to deal with the conversion of buildings was that under the existing regulations it would be possible, for example, for any person to design a building for domestic purposes with floor loads calculated at the rate of 70 lb. per sq. ft. Afterwards the building might change hands, and it might be used for the purpose of a warehouse in which the loads might be more than three times as great as formerly. There was no power in the Act of 1909 to make regulations to control such conversion of a building by mere change of user, and there would be no remedy under the Building Acts unless the District Surveyor became aware of some condition of imminent danger. In the case of ordinary forms of construction it was possible to ascertain the probable strength of the supporting members, but in the case of reinforced concrete the sizes and the disposition of the bars might be unknown, so that greater precaution was necessary in this type of construction. The change in the use of a building might involve structural alterations or it might not, and the latter case was dealt with in Sub-clause (3) which provided that conversion of a building should include change of user. Sub-clause (2) of Clause 5 provided that in order to facilitate the erection of any particular building constructed wholly or partly of reinforced concrete, or the conversion of any building, the Council might modify or waive any of the requirements of the regulations made under Section 23 of the Act of 1909. The object of this provision was to enable the Council to grant relief from any of the regulations in cases where it was satisfied that relief could reasonably be granted. The clause was based upon Section 22, Sub-section (34), of the Act of 1909, which empowered the Council to waive or modify any of the requirements of eleven sub-sections of that section in relation to buildings of steel-frame construction. This power proved to be so beneficial that in 1923 it was extended by Section 5 of the London County Council (General Powers) Act, 1923, to eighteen other sub-sections of Section 22 of the Act of 1909, and numerous applications had been dealt with by the Council under those Acts. Although requested on various occasions to waive or modify similarly the reinforced concrete regulations, the Council had been unable to do so owing to there being no statutory authority, and the present power was sought to enable the Council to deal with such applications. The allegation of the petitioners that the Bill did not require the Council to give notice to them as to regulations made under the extended powers now proposed appeared to be entirely erroneous. Clause 5 of the Bill provided that the Council might make regulations subject to the provisions of Section 23 of the Act of 1909. Sub-section (4) of that section required notice to be given to the Institutions mentioned, and this procedure would apply to any regulations made under the present Bill. There was no intention of not giving notice. He agreed that the right of appeal under the 1909 Act related to matters of stability as well as to matters of detail, although in 1923 the Council was given power to relax or modify the regulations in cases relating to stability. There was no opposition in Parliament to the 1923 Bill, and no suggestion that there should be a right of appeal. It was essential that the Council should have absolute power on questions relating to stability.

Cross-examined by Mr. Henderson: Under the 1894 Act, are you able to deal with conversion of other than reinforced concrete buildings?—Yes.

The Tribunal of Appeal set up under the Act of 1894 proved very useful?—Yes.

Witness agreed that there were a considerable number of appeals under the Act of 1894, and that as guided by the Tribunal practice and procedure had become more or less settled, with the result that very few appeals came before the Tribunal now.

Mr. Henderson: As the Tribunal has been so useful, do you not think that when you are dealing with a new form of construction it is more than ever necessary to provide some check on the decisions of the Council by giving the right to appeal to the Tribunal?—I think on the question of stability the Council should be the last authority. He was prepared to allow a right of appeal on matters other than stability.

Under the 1909 Act certain sections

dealing with stability are subject to the right of appeal ?—Yes.

Under the Bill you do not propose to allow a right of appeal in any case ?—No.

Let us see how far this Bill takes us. A steel-frame building with a reinforced concrete floor is to-day governed by the steel-frame regulations in Section 22 of the Act of 1909. The Council authorises the frame and the District Surveyor deals with the floors. If Section 5 of the Bill is passed, any alteration made to such a building will immediately make such a building subject to the regulations for buildings constructed " wholly or partly of reinforced concrete," and there will be no right of appeal from the decisions of the Building Acts Committee ?—Yes.

In reply to the Chairman, witness said he had no objection to the right of appeal being granted to converted buildings in which use was made of reinforced concrete.

In his concluding speech, Mr. Henderson said on behalf of the four petitioning societies he was happy to say that the answers given by Mr. Tasker and Mr. Topham Forrest had settled the points with which they were chiefly concerned. As things now stood the societies were entitled to have new regulations submitted to them, and they could comment on them, but whether their suggestions were adopted or not was entirely a matter for the Council. The societies would like to have authority to be able to make direct representation to the Minister of Health, and he would like to know whether the Council had any objection to that course being taken. On that point Mr. Topham Forrest had said he had not the slightest objection. Under Section 22 of the 1909 Act Parliament specifically confined this legislation to the framework of a steel-frame building, with one condition, that the girders should be strong enough to carry certain superimposed loads on the floors. When the Council issued its regulations dealing with reinforced concrete they were limited to buildings wholly or partly of reinforced concrete, or which were partly of skeleton frame construction of reinforced concrete and partly reinforced concrete frame and party walls. So long as the clause was confined to that the societies were quite content that the Council should possess such power. But Clause 5 of the Bill spoke of " any building or part of a building constructed wholly or partly of reinforced concrete, or the conversion of any particular building or part of a building so constructed," and the societies feared that these regulations would be made to apply to any building that had any reinforced concrete in it at all. If, for instance, a brick building with a reinforced concrete floor were altered in any way, this Bill would bring that building under the regulations for reinforced concrete construction. But their fears on this ground were removed by the answers of Mr. Topham Forrest. He suggested that the Council should recast the clause so as to make quite clear the kind of building to which it desired the regulations to apply, and that the description " buildings wholly or partly of reinforced concrete " should not be allowed to stand. As to the question of appeal, the Council sought to make regulations which they would be able to waive or modify, but at the same time there would be no right of appeal from its decision on questions of stability. The regulations were not yet made, and how was the Council to determine which related to stability and which did not ? The only wise course was to say that any of the regulations should be subject to the right of appeal in the event of the Council refusing to waive or modify them, for there was a right of appeal already in existence against the decisions of the Council on matters of stability in connection with public buildings.

Mr. Charteris : I suggest on behalf of the Council that in order to give effect to the views expressed by Mr. Forrest it be made perfectly clear that Section 27 of the principal Act be included in the Bill.

The decision of the Committee was as follows : " Clause 5 of the Bill is to stand, except that the question of appeal is to be brought into line with the Act of 1909."

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	6
Thames ballast	,,	10	6
Broken brick (¾ in.)	,,	11	6
Best British Portland Cement	per ton 58*s.* to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10*s.* per ton extra		
"Super-Cement"	per ton 88*s.* to	93	0
"Lightning" Brand Aluminous Cement	,, 100*s.* to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	*Sawn.* d.	*Wrot.* s.	*Wrot.* d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £20 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
5/16 in. to ½ in. Rounds	,,	10	9
⅜ in. Rounds	,,	11	0
¼ in. Rounds	,,	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do	do.	in foundation	per foot cube	1	11
Do.	do.	in columns	,, ,,	2	1
Do.	do.	in beams.	,, ,,	2	3
Do.	do.	in floor slabs 4 in. thick	per yard super	6	0
Do.	do.	in floor slabs 5 in. thick	,, ,,	7	6
Do.	do.	in floor slabs 6 in. thick	,, ,,	9	0
Do.	do.	in floor slabs 7 in. thick	,, ,,	10	6
Do.	do.	in walls 6 in. thick	,, ,,	8	8

(Add for hoisting 3*s.* 6*d. per yard cube above ground-floor level. Add for "Ferrocrete"* 1*s.* 10*d. per yard cube.)*

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
,, 5/16 in. to ½ in.	,,	21	6
,, ⅝ in. to 2⅞ in.	,,	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	,, ,,	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	,, ,,	1	1½
Do. do. as last, in narrow widths	,, ,,	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	,, ,,	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

Aberdeen.—*Houses.*—The T.C. has applied for sanction to erect 318 houses.

Aberdeen.—*Streets.*—Streets are to be constructed at Newlands, Craigiebuckler, Tanfield and Desmount Avenue.

Airdrie.—*Houses.*—The T.C. proposes to build 150 houses.

Atherstone (Warwickshire).—*Houses.*—The R.D.C. proposes to build 105 houses in various parishes.

Bacup.—*Houses.*—The T.C. proposes to erect 234 houses.

Barnsley.—*Houses.*—Application has been made for sanction to a loan of £28,010 for housing purposes.

Bebington.—*Houses.*—The U.D.C. has applied for permission to erect 100 houses.

Birmingham.—*Houses.*—The Corporation has prepared a scheme for the erection of 2,500 houses on the Fox Hollies estate.

Bloxwich.—*Road.*—The Walsall T.C. has applied for sanction to a loan of £38,000 for the construction of a road from Leamore to Bloxwich.

Bognor.—*Houses.*—The Surveyor has been instructed to prepare plans for the erection of 44 houses.

Bridlington.—The T.C. proposes to purchase land on Sewerby Cliffs for the provision of a footpath.

Brighouse.—*Houses.*—The T.C. has applied for a loan of £17,750 for the erection of 40 houses on the Smith House estate.

Brighton. — *Houses.* — The Health Committee recommends the Corporation to prepare plans for the erection of 60 houses on the Bristol estate.

Burley.—*Houses.*—The R.D.C. proposes to erect 36 houses.

Burnley.—*Roads.*—The Burnley Corporation proposes to construct two arterial roads.

Cambuskenneth.—*Bridge.*—The Stirling T.C. proposes to erect a bridge at Cambuskenneth Ferry.

Cannock.—*Streets.*—The U.D.C. proposes to construct two streets leading off St. John's and Walsall Roads.

Cannock.—*Houses.*—The U.D.C. has applied for sanction to a loan of £16,920 for housing purposes.

Carmarthen. — *Bridge.* — The County Council is considering a scheme for the construction of a two-level bridge over the River Towy.

Cheltenham.—*Houses.*—The T.C. is recommended to build 147 houses.

Chesterton. — *Houses.* — The R.D.C. has applied for sanction to erect 84 houses.

Chester-le-Street.—*Houses.*—Application has been made for sanction to a loan of £31,500 for housing purposes.

Chopwell. — *Road.* — The Blaydon R.D.C. proposes to construct a road between Chopwell and Spen.

Clifford Chambers. — *Bridge.* — The Warwickshire and Gloucestershire County Councils have decided to construct a bridge across the River Stour at Clifford Chambers. The cost will be £10,100.

Coventry. — *Concrete Bridge.* — The T.C. will receive a grant from the M.T. of 65 per cent. of the estimated cost of £55,500 for constructing a reinforced concrete bridge at Lockhurst Lane.

Dudley.—*Houses.*—The T.C. has applied for sanction to a loan of £17,182 for the erection of 58 houses.

Dukinfield.—*Houses.*—The T.C. proposes to erect 100 houses in Clarendon Fields.

East Moors.—*Bridge.*—The Helmsley R.D.C. is considering a scheme for the construction of a bridge over the beck at East Moors.

Essington. — *Road.* — The Cannock R.D.C. has submitted to the M.T. plans for the construction of a road at Warstone Essington.

Exeter. — *Houses.* — The Devonshire C.C. has instructed the County Architect to prepare plans for the erection of 102 houses for the employees of the Council. The cost is estimated at £60,500.

Faversham.—*Road.*—Plans have been prepared for the construction of a road from Faversham to Thanet. The estimated cost is £1,000,000.

Goole.—*Houses.*—The U.D.C. is to build 50 houses in Westfield Avenue.

Gosport.—*Houses.*—The Corporation has applied for sanction to borrow £76,320 for housing purposes.

Hakin.—*Bridge.*—The Milford R.D.C. is negotiating with the Haverfordwest R.D.C. with a view to building a bridge at Hakin.

Harrogate. — *Houses.* — The T.C. is considering a scheme for the erection of 50 houses in Ripon Road.

Hastings.—*Houses.*—The T.C. proposes to build 50 houses at Ore.

Hendon.—*Houses.*—The U.D.C. is considering a scheme for the erection of 52 houses on Child's Hill.

Horsham.—*Bridge.*—A sum of £426 is to be spent on the construction of a bridge in Blackbridge Lane.

Houghton-le-Spring.—*Houses.*—The R.D.C. has applied for sanction to build 100 houses.

Hull.—*Bridge.*—The Corporation proposes to erect a bridge over Barmston drain.

Kettering.—*Houses.*—The U.D.C. is negotiating for a site on which to erect 325 houses.

Leeds. — *Houses.* — The Corporation proposes to erect 500 houses on a site at York Road and 361 houses on a site at Oakwood Lane.

Liverpool.—*Promenade.* A scheme is being considered for the construction of a promenade from the south docks at Liverpool to the Otterspool estate.

Llanfairfechan.—*Concrete Groyne.*—The U.D.C. has instructed the Surveyor to prepare plans for the construction of a concrete groyne on the foreshore.

Lye.—*Houses.*—The U.D.C. has applied for sanction to a loan of £24,050 for the erection of 52 houses.

Maidstone.—*Houses.*—The T.C. proposes to build 500 houses during the next eighteen months.

Merthyr.—*Houses.*—The T.C. proposes to build 100 houses on a site at Troedyrhiw.

Newcastle-on-Tyne.—*Houses.* — The Corporation proposes to build 880 houses. The cost is estimated at £398,504.

Oldham.—*Cottages.* The Corporation proposes to spend £40,000 on the erection of 100 cottages.

Pennant. — *Bridges.* — The Glaslyn R.D.C. is considering plans for the erection of bridges at Pennant.

Plymouth. — *Concrete Houses.* — The T.C. has applied for sanction to a loan of £78,000 for the construction of 166 "Easiform" concrete houses.

Portsmouth.—*Houses.*—The Corporation has applied for sanction to borrow £119,500 for the erection of 500 houses on Portsdown Hill.

Richmond (*Surrey*).—A bridge is to be constructed in place of the Black Horse level crossing. The cost is estimated at £12,250.

Salford.—*Houses.*—The C.B. has applied for sanction to build 42 houses. The cost is estimated at £23,400.

Saltash.—*Houses.*—The T.C. proposes to build 40 houses.

Seghill.—*Houses.*—The U.D.C. has applied for permission to build 28 houses.

Shipley.—*Houses.*—The Surveyor has been instructed to prepare plans for the erection of 70 houses.

Tenders Accepted.

Blackburn. — *Concrete Bridge.* — The Corporation has accepted the tender of Messrs. Etheridge & Leach, Cheetham Hill, Manchester, for the construction of a reinforced concrete bridge across the canal at Shorrocks Lane.

Burnley.—*Foundations.*—The Corporation has accepted the tender of Messrs. Wellerman Bros., Sheffield, at £4,340 5s., for excavating and concrete work for the foundations at the Old Hall gasworks.

Croydon.—*Concrete Wall.*—The T.C. has accepted the tender of Mr. R. Mansell, Croydon, at £899, for the construction of a reinforced concrete wall on the Waddon housing estate.

Eastbourne.—*Concrete Houses.*—The T.C. recommends the acceptance of the tender of Messrs. Underdown, Ltd., for the construction of six concrete houses at £516 each.

Findochty.—The T.C. has accepted the tender of Messrs. W. & J. Sykes, Middlesbrough, at £21,392, for the construction of a 250-ft. jetty and a 457-ft. reinforced concrete quay wall.

Ilkeston. — *Concrete Water Tower.*— The Corporation has accepted the tender of the Yorkshire Hennebique Contracting Co., Ltd., at £4,233 14*s.* 5*d.*, for the construction of a 60,000-gallon reinforced concrete water tower. Other tenders submitted were: Bridge Engineering Co., £4,011 4s.; Anglo-Danish Concrete Construction Co., Ltd., £4,650; and G. F. Tomlinson, £6,477.

Southwold. — *Concrete Wall.* — The T.C. has accepted the tender of Messrs. Bugbird & Co., Aberystwyth, at £6,560, for the construction of a concrete wall on the sea front. Other tenders submitted were: J. Gill & Co., Ltd., £8,274;

R. J. May, £7,400; A. Fasey & Son, £7,250; and W. Church, £6,739.

Tunbridge Wells.—*Concrete Houses.*—The T.C. has accepted the tender of the Universal Housing Co., Ltd., at £23,562 15*s.* 6*d.*, for the construction of 50 concrete houses at Ashley Park.

Upperchurch (*Ireland*). — *Concrete Church.*—Messrs. Walsh Bros., of Clonmel, have secured the contract for the erection of a reinforced concrete church at Upperchurch.

Weston-super-Mare.—*Bridges.*—The Somersetshire C.C. has accepted the tender of the Durnford Construction Co., Ltd., Bristol, at £2,747 3*s.*, for reconstructing and widening in reinforced concrete the Week and Coppleham bridges. Other tenders submitted were: J. Coles & Son, £4,056 10*s.* 2*d.*; Coles, Bros., Ltd., £5,895; Fothergill Bros., Ltd., £5,641 9*s.* 9*d.*; G. Pollard & Co., Ltd., £5,256 7*s.* 11*d.*; E. Ireland, £5,700; F. & E. Small, £5,616 1*s.* 4*d.*; G. B. Fisher, £2,842 11*s.*; Roads Constructions, Ltd., £4,199 7*s.*; and H. Coxhead & Co., Ltd., £4,331 1*s.* 9*d.*

Woolwich (*London*).—*Concrete Houses.*—The B.C. has accepted the tender of Messrs. John Laing & Son, at £238,822 19*s.*, for the erection of 500 concrete houses.

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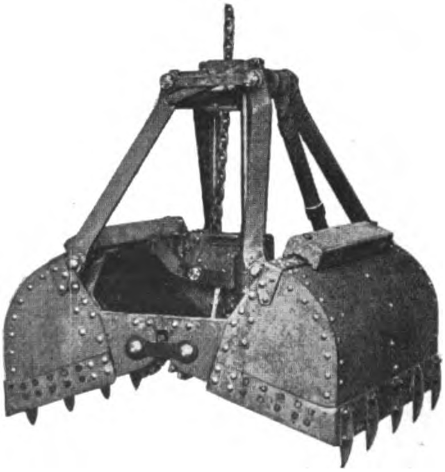

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AUGUST 1926 CONCRETE SERIES Nº1 VOL. XXI No. 8

TWENTY-FIRST YEAR OF PUBLICATION

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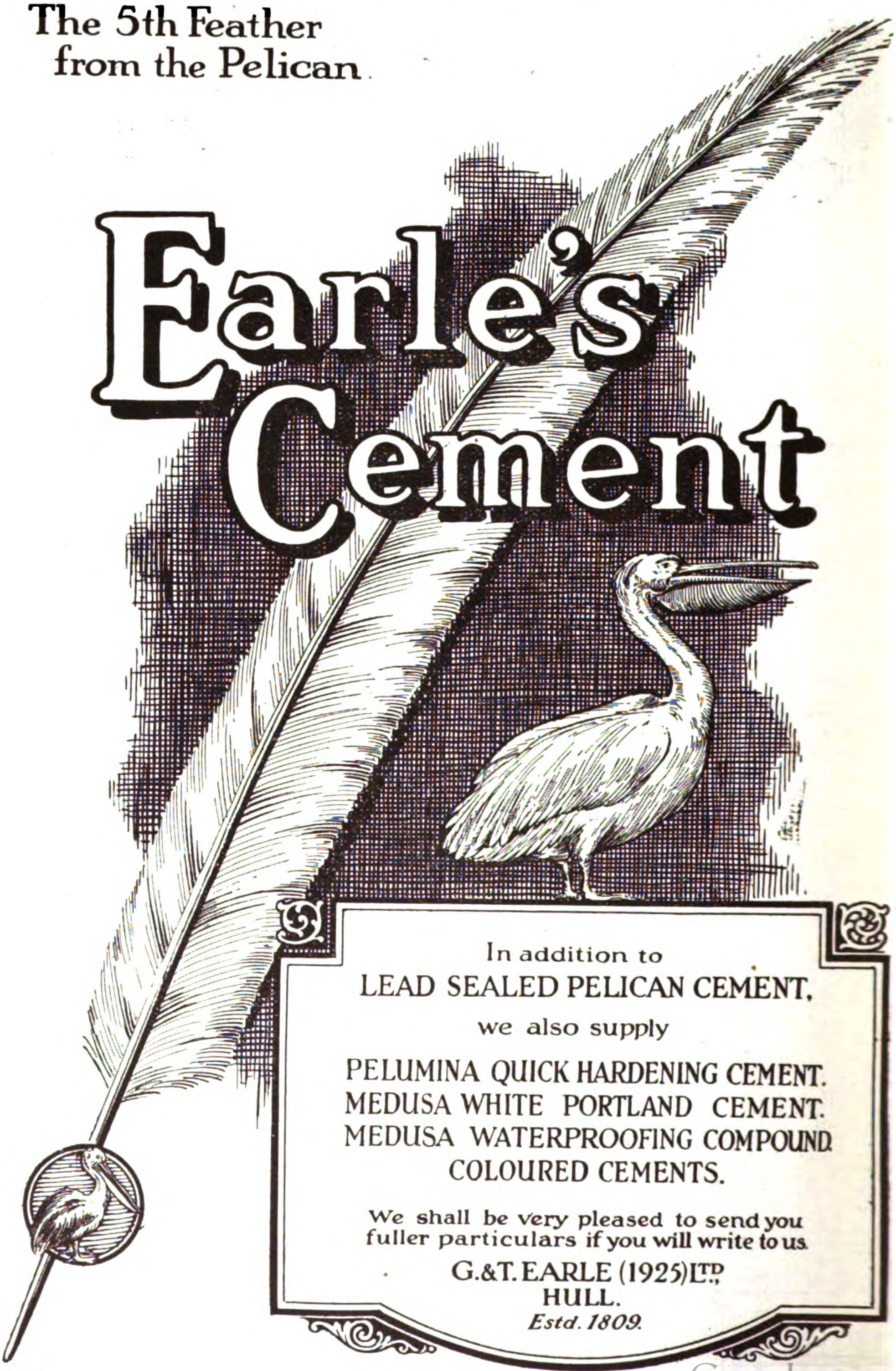
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CONCRETE
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Volume XXI. No. 8. LONDON, AUGUST, 1926.

EDITORIAL NOTES.

"Concrete and Constructional Engineering" Prize Design.

IN this issue we give the winning design, by Miss Jessie M. Greig, which has been awarded the "Concrete and Constructional Engineering" Prize for Concrete Design at the University of London School of Architecture. The subject set by Professor A. E. Richardson, F.R.I.B.A. (Professor of Architecture of London University), was a Pavilion in Reinforced Concrete on the Serpentine, and the competition resulted in some very fine sets of drawings. The Jury which made the award consisted of Mr. H. V. Lanchester, F.R.I.B.A., Mr. Arthur Davis, F.R.I.B.A., Mr. C. L. Gill, F.R.I.B.A., Mr. H. Corfiato, A.R.I.B.A., and Professor Richardson.

As will be seen from the winning design and the design placed second, by Mr. F. Jenkins (also illustrated), the students under the able supervision of Professor Richardson and Mr. Corfiato, thoroughly realise the architectural possibilities of reinforced concrete, and have created something quite out of the ordinary. They have given their designs an air of gracefulness and lightness which, although frequently seen in stands on racecourses on the Continent and particularly in South America, is seldom seen in this country. We imagine, in fact, that few architects in this country realise reinforced concrete can be used with such effect at all. We congratulate Miss Greig on having produced a design so fitting to its purpose, and hope she may some day have an opportunity of carrying out such a building; certainly it would add to the amenities of London's outdoor life.

The "Concrete and Constructional Engineering" Prize (value £25) is awarded annually at the University of London School of Architecture for the encouragement of design in reinforced concrete, and will, we hope, do much to imbue the rising generation of architects with the possibilities of the material.

Reinforced Concrete Regulations.

THE London County Council (General Powers) Bill, 1926, which contains clauses empowering the Council to extend the Section of the Act of 1909 relating to reinforced concrete to cover "the conversion of any building or part of a building constructed wholly or partly of reinforced concrete," and also giving the Council power to modify or waive any of the regulations under the 1909 Act at the Council's discretion, progressed a stage further last month.

As reported in our last issue, the Bill was opposed by the Institution of Civil

Engineers, the Royal Institute of British Architects, the Surveyors' Institution, and the Institution of Structural Engineers, and also by the Ministry of Health, whose petitions were heard by a Select Committee of the House of Lords in June. The principal opposition was to the Clauses in the Bill applying the regulations to buildings wholly or partly of reinforced concrete, including conversions, and to the absence in the Bill of any right of appeal against the decisions of the London Building Acts Committee, as exists in the case of steel frame construction. After a long hearing, the Select Committee decided that the Clauses should stand, except that there should be the same right of appeal to the Tribunal of Appeal as existed in the case of steel frame construction. After the first hearing there were several informal conferences between the London County Council and representatives of the technical societies, as a result of which the Council inserted additional Clauses giving the societies all they asked for in the public interest. These clauses are very important, including, for instance, provision that the new regulations as regards conversion shall not apply to buildings built under the 1924 Act or the Steel Frame Act of 1909.

Last month the Bill was considered by the Local Legislation Committee of the House of Commons, presided over by Sir Thomas Robinson, when the only opposition came from the Ministry of Health, who asked that the exercise of the power of waiver should be subject to the approval of the Ministry, after public advertisement and giving notice to the four professional societies. An official of the Ministry stated that the objection was principally based on the possibility under the Bill of the discrimination of the Council between different methods of building construction and the products of different manufacturers. In reply, it was submitted on behalf of the Council that the object was to encourage building in reinforced concrete, and that the delays involved in the procedure suggested by the Ministry would defeat the objects of the Bill; reinforced concrete design was constantly changing and improving, and it was the desire of the Council to be in a position to sanction with a minimum of delay new methods which were found to be satisfactory by its advisers.

After consultation, the clause was allowed by the committee, which expressed its belief that the Council could be relied upon to discharge its obligations satisfactorily.

Concrete Motor Roads.

THERE have been several schemes mooted for the construction of high-speed motor roads between important centres in this country, but so far none of them has come to fruition. In Italy, however, it appears that concrete motor roads are being extensively undertaken, with the moral and financial support of the Italian Government. The first of these schemes was put forward in 1921 by the firm of Puricelli, Italy's biggest road-building concern, and received the unconditional support of Signor Mussolini. The proposal was to build a straight road from Milan to Lakes Como, Maggiore, and Varese, traversing important industrial districts. The total length is 53 miles. The firm of Puricelli and the Government are jointly interested in a new company which has been formed to construct the road; the company will own the road for a period of fifty years, during which time it will retain the tolls, and the road then becomes the absolute property of the State without the payment of any compensation to the Company. In return, the Government is giving an annual sum to the Company to serve as a guarantee to the shareholders for interest and amortisation services. The tolls for the use of the road work out at about a penny a mile, with reductions for long and return journeys.

In view of the magnitude of the scheme, different methods of construction were carefully examined, and after investigations in the United States and elsewhere, it was decided to use reinforced concrete, 8 in. thick, topped with a tar dressing. The concrete is mixed in the proportion of 1 part Portland cement to 3½ parts gravel and sand.

Much is being done in this country in the construction of arterial roads and widening of important existing roads, at enormous expense to the local authorities and the national exchequer, but much has still to be done before our roads as a whole are adequate for the increasing traffic put upon them. The payment of tolls would naturally not be welcomed by a nation which has, for nearly a hundred years, been accustomed to the free user of roads, but if the payment of a comparatively small fee for the use of a fast road while alternative free roads are still available would add sufficiently to the resources of the Road Fund to permit more wide and fast roads to be put in hand, it would be a good thing for the country, for roads are now as essential as railways to the carrying on of commerce. It is probable, too, that the tolls which make possible the construction of the roads would be recovered by the users in the form of lower petrol consumption, greater speed, and a reduction of wear and tear.

Concrete for Private Street Works.

An important sequel to a recent case in the Kingston Petty Sessional Court (reported in our issue for March, 1926) is reported. Certain residents, it will be remembered, received notice that the Maldens and Coombe Council proposed to lay all-concrete roads at the expense of the adjoining property owners. A vigorous protest was immediately made by these owners, who declared that such roads would last indefinitely—even longer than their houses—and that they ought not to have to bear the whole cost of roads intended for posterity.

Under the Private Street Works Act the matter was taken to court in order that a ruling might be obtained on the point. The proceedings attracted wide public interest, and after a long hearing the court supported the owners and ordered the Council to amend the specification to provide for roads similar to those then existing, which were of waterbound macadam.

Tenders were therefore invited, and separate estimates for the work in concrete, flint, and tar-macadam were received. The estimate for concrete proved the lowest, the average prices per foot of frontage being as follows: Concrete, 28*s.* 9*d.*; flint, 31*s.* 4*d.*; tar-macadam, 33*s.* 7*d.* In the light of these figures, the property owners concerned have now intimated to the Council that they are willing to withdraw their objection to all-concrete roads. These figures bear out the testimony of experts who gave evidence in the case, when they stated that there was no ground for the action as in proposing to use concrete the Council had selected the cheapest as well as the most durable material.

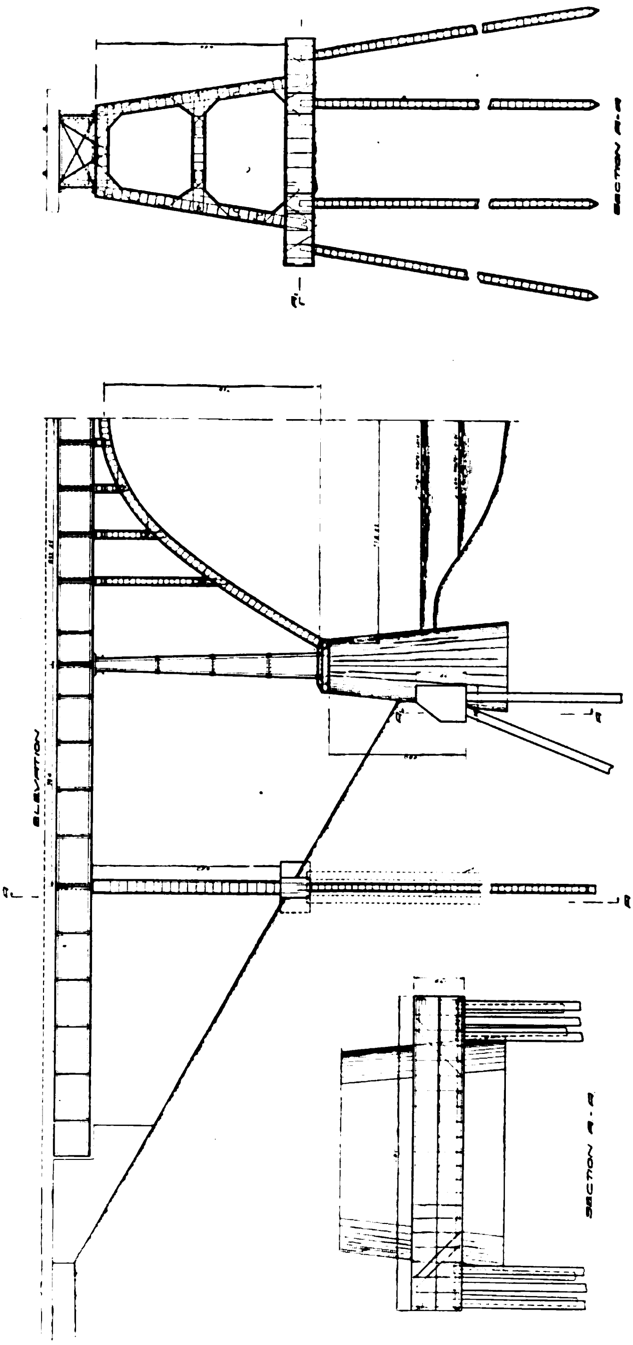


Fig. 2.—Method of Strengthening Nåså Bridge. (*See p.* 545.)

Strengthening Existing Bridges.

By OVE ARUP.

ONE of the problems with which the designer of bridges is frequently faced is the reconstruction or strengthening of existing bridges in order to enable them to withstand the stress of steadily increasing road or rail traffic ; and the fact that this reconstruction often has to be carried out without interference with the existing traffic—as is frequently the case with railway bridges—particularly adds to the difficulty of the problem.

Generally, this difficulty is overcome either by altering the position of the permanent way so that an entirely new bridge can be built independent of the traffic, or by leading the traffic over a temporary bridge while the reconstruction of the old bridge is carried out. In the case of a bridge carrying several tracks there is also the possibility of reconstruction in sections.

There are cases, however, where these possibilities are practically out of the question, and where a solution of the problem requires that a strengthening of the existing bridge be carried out while the traffic over the bridge is maintained. Where it is possible to do this it will generally also prove to be the cheapest method. It may therefore be of interest to learn how this problem has been tackled in the case of three single-track railway bridges in Sweden.

In 1923 enquiries were sent out to a number of firms for the reconstruction of the railway bridges over the rivers Tunaå, Nåså and Klinteboå, in Sódra Dalarne, Sweden. The bridges were originally constructed for an axle load of 14 tons and a speed of 50 miles per hour, and it was desired that they should be strengthened to enable them to carry an axle load of 18 tons with a speed of 62 miles per hour. Contractors were left free to adopt any method which they thought fit, the only condition being that the section of the stream had to be maintained. In all seventy-eight proposals were received, of which the scheme described below, submitted by Messrs. Christiani & Nielsen, was adopted.

Fig. 1 shows the original construction of the bridge over the river Nåså. The other two bridges were quite similar to this, except that the bridge over the river Tunaå was in five spans instead of three. As will be seen from *Fig.* 1, the construction was that of a continuous plate girder bridge. The spans varied from 48 to 55 ft. The piers and abutments were carried out in granite masonry, which in the case of the Nåsa and Klinteboå bridges was founded on piles, while the foundations for the Tunaå bridge were carried down to a firm ground.

Fig. 2 shows how the strengthening was carried out in the case of the bridge over the river Nåså, and the procedure was similar for the other two bridges. In the middle span a reinforced concrete arch supported on the existing piers was constructed under each girder, and eight reinforced concrete trestles were carried from the arches up to the underside of the girders. In the outer spans the girders were supported in the middle by

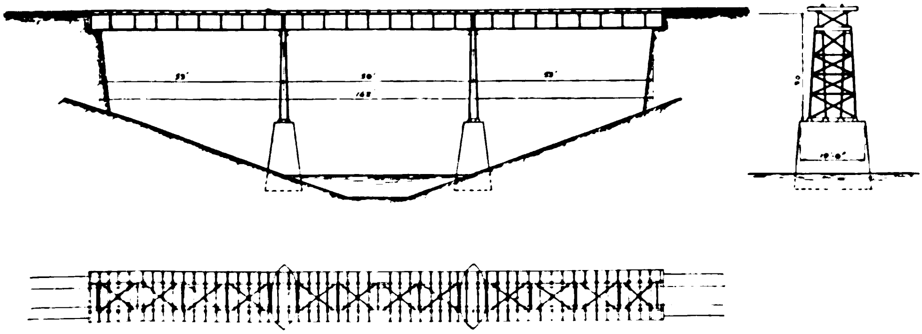


Fig. 1.—Original Construction of Nåså Bridge.

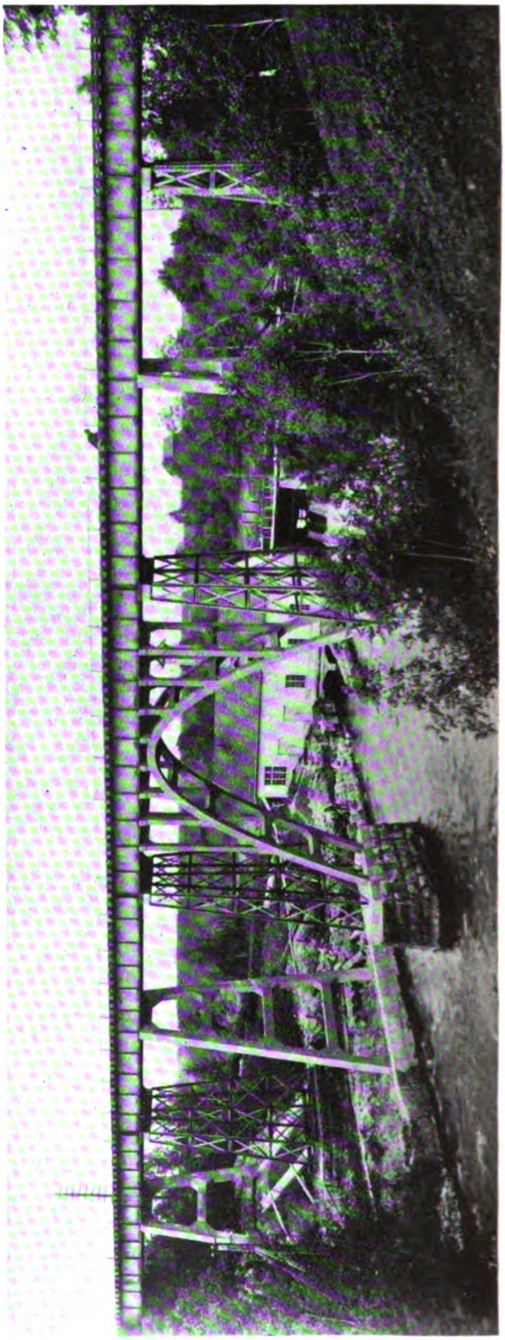


Fig. 4.—Strengthening of Tunaå Bridge Completed.

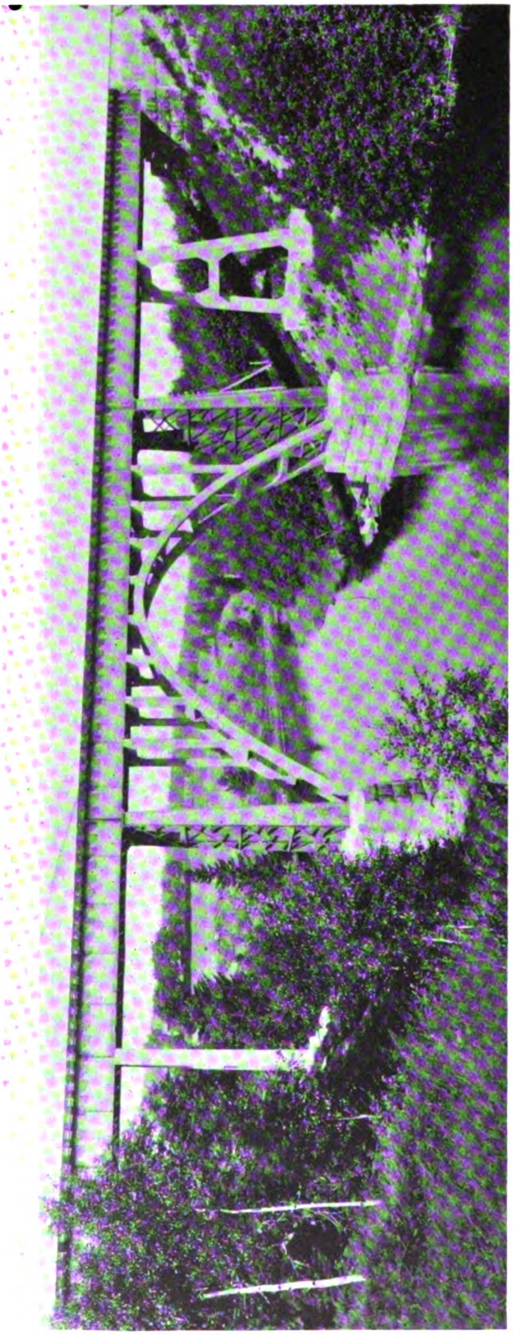


Fig. 5.—Strengthening of Nåså Bridge Completed.

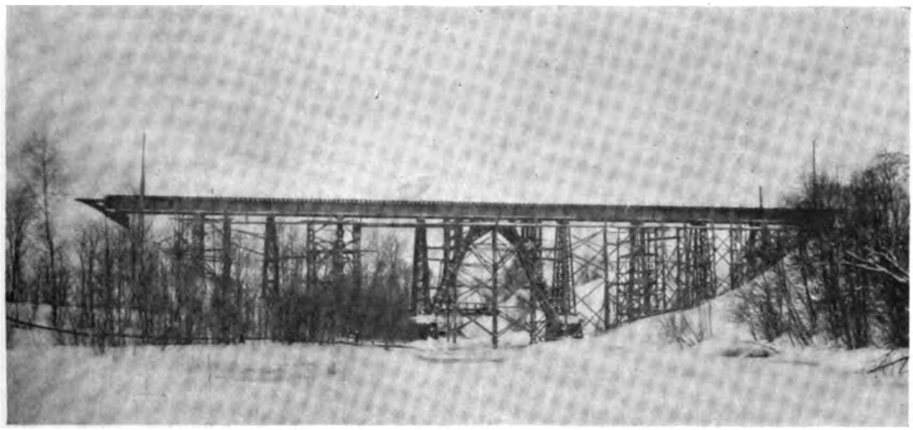


Fig. 3.—Strengthening of Tunaå Bridge in Progress.

reinforced concrete trestles on separate pile foundations. In each case the supporting trestles were carried up to a distance of about 2 in. from the underside of the plate girders, the remaining 2 in. being filled up with aluminous cement concrete after the complete hardening of the structure. There were eight hours between the last train in the evening and the first train in the morning, and this time was sufficient to enable the concrete to acquire the strength necessary to prevent it from being damaged by vibration.

Fig. 3 shows the work at the Tunaå bridge under construction. The concrete is cast, but the centering is not stripped yet. It will be seen that the scaffolding and centering are erected quite independent of the existing steel structure, in order that the vibration shall not affect the concrete. In this case the winter came so early that it was thought advisable to postpone the casting of the aluminous cement concrete foundations until the Spring.

Figs. 4, 5, and 6 show the finished structures. The slenderness of the arches and the simplicity of the design give them quite a pleasing appearance.

The method of casting additional bearings for the old structure in rapid hardening concrete has a great advantage from a calculation point of view, as it gives a good basis for the computation of the loading taken by the new structure. This question is generally one of considerable difficulty in the case of the strengthening of existing structures, and where wedges, screws, or similar means are applied to effect a support for the old structure the distribution of the loads is very uncertain.

In this case, however, it is clear that the whole of the dead load of the old bridge is taken by the old girders, whereas the live load is distributed between the old and the new structure in proportion to their respective elasticity, or, more exactly, a load which is applied at one of the points of contact between the old and the new structure will be distributed between these two in inverse proportion to the deflections that would be caused in the old and the new structure by a unit load applied at that point.

As the plate girders in this case are very stiff compared with the relieving arches in the middle span, the two structures act together as an arch with a stiffening girder, so that the whole construction constitutes a " Langer girder." The stresses have been calculated by two different methods. By the first the stiffness of the arch was altogether ignored, and by the second a more exact calculation was carried through by which the stiffness of the arch was taken into account as far as both temperature stresses and stresses for the live load were concerned. The difference in the results of the two calculations was for this construction less than 10 per cent. so that the first method was quite a good approximation.

Regarding the piers, only the outer measurements of the granite masonry

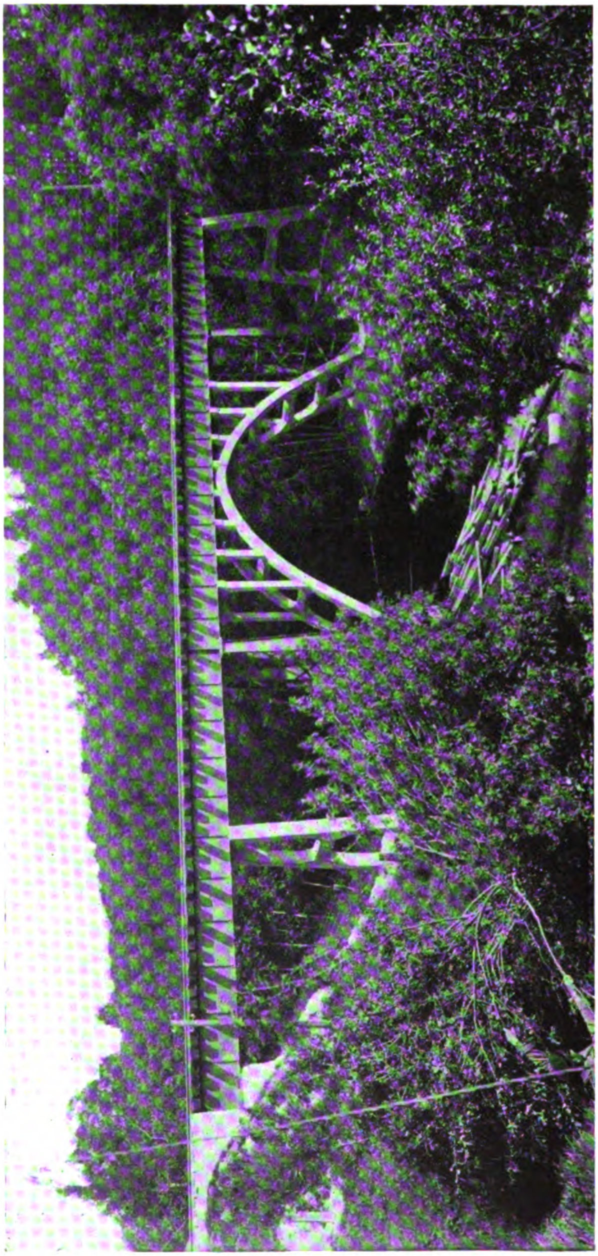


Fig. 6.—Strengthening of Klinteboå Bridge Completed.

were known, while no information as to the number and strength of the piles was at hand. In the case of the end piers this was of no importance, as the load on these piers at any rate was less than before, whereas in the case of the middle piers the load was increased with a horizontal as well as a vertical force from the arches. In order to ensure that the existing piles were not stressed more than before, these piers had to be strengthened. *Fig.* 2 (sections A_1 A_1 and A_2 A_2) shows how this strengthening was carried out. Three raking and two vertical piles were driven at each side of the existing pier, and the arch thrust was transferred to these piles by means of a heavy reinforced concrete beam which was built into the existing pier.

In addition to being supported vertically, the plate girders were also supported horizontally by reinforced concrete brackets, as can be seen from *Fig.* 2. Thus a very effective strengthening of the girders was obtained by the method adopted, and no alteration to the steel construction was necessary.

The other proposals submitted were based on one of the following methods :—

(1) The construction of an entirely new reinforced concrete arch bridge underneath and at the sides of the existing bridge on entirely new foundations. When the bridge was finished the existing girders were to be taken down and the track was to be carried on earth filling.

(2) The construction of a new steel bridge on the old foundations. The demolition of the old bridge and the placing of the new bridge would have been carried out in the course of one night.

(3) Strengthening of the existing bridge by means of a steel construction and a strengthening of the piers in a way similar to that adopted.

All these methods, however, were far more expensive than the method adopted, and as no disturbance of the traffic whatever was necessitated, the method proved quite a success, and could well be adopted with advantage in similar cases.

The bridges have now been subjected to the heavy loading for over a year, and are giving satisfaction in every respect.

Aggregate for Concrete Floors.

The Association of Floor Constructors has had under consideration regulations which govern the construction of steel and concrete floors, and in particular the use of coal residues in concrete which is in any way in contact with steel. The Association states : " Having regard to the many cases in which this material has been clearly proved to have corroded the steel, often to the extent of entire destruction, the Association has decided to approach the Government, and all County, Borough and District Councils to take steps to prohibit the use of coal residues in structural concrete in contact with steel. In this connection, it is worthy of note that the revised building regulations of other countries prohibit the use of this material for the class of work mentioned."

Concrete Garages.

A booklet of 24 pp. dealing with the construction of concrete garages has been issued by the British Portland Cement Association, of Portland House, Tothill Street, S.W.1, and will be sent post free on request to interested readers of this journal. The booklet is divided into two distinct parts, the first containing general remarks on the fire-resistance and stability of concrete and dealing generally with the general methods of construction, and the second part giving three designs for concrete garages, by Mr. Douglas Wood, F.R.I.B.A., costing between £100 and £120 in the London area.

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—*Ed.**

Concrete Sewer Pipes.

Question.—Can there be any objection to the use of pipes manufactured in reinforced concrete for use as sewers, i.e. is there any deleterious chemical action on the concrete due to the presence of sewage? My own impression is that since so many septic tanks are constructed of this material it follows that there is no deleterious effect.—R. P. M.

Answer.—Pipes of reinforced concrete are used as sewers very extensively, and we have no knowledge of any which have been damaged by corrosion specifically due to sewage. Even brick sewers are set in cement mortar, so that they would be liable to deleterious action also if there were any.

Bond Stress.

Question.—In designing slabs, beams, etc., for reinforced concrete, investigation for bond stress is often omitted from textbooks. What is the working stress for ordinary concrete slabs with half the steel diagonally bent up, passing over the longitudinal beams?

Would the formula:—

$$\frac{\text{end shear}}{\text{j.d. sum of perimeters of bars in } 12'' \text{ width}}$$

be used in the ordinary way? Can you give an example?—E. T.

Answer.—The working stress for the adhesion is 100 lbs. per sq. in. whether half the steel is bent up diagonally or not. In our view only the rods running along the bottom of the slab should be taken into account in calculating the area for adhesion, except where the diagonal rods are bent up immediately adjacent to the support. As a rule they are, of course, bent up not at this point, but at a point nearer midspan of the slabs, generally somewhere about quarter span so as to provide top steel for reverse bending moment, and in such cases they should not be taken into account in calculating adhesion.

Bridge Testing.

Question.—I should be obliged if you would advise me as to the correct method of testing a ferro-concrete bridge designed for Ministry of Transport loading. It will be very instructive if you will quote any variation in method for testing an arch, vault, beam and slab, and the ordinary slab decking.—W. G. M.

Answer.—Ferro-concrete bridges designed for Ministry of Transport loading are generally loaded with trains of traction engines and trailers. The Ministry of Transport loading states the actual dead weight of the train for which the bridge is designed, and adds 50 per cent. on to this to allow for impact. The lower of these two weights ought therefore to be adopted for the actual weights of the train used in testing, but inasmuch as the percentage to be allowed for impact depends on the quality of the surface of the road, which is presumably much better at the date of testing when the bridge is new than it will be subsequently, it is not uncommon or unreasonable to take a train weighing 25 per cent. in excess of the loads for which the bridge is supposed to be designed, so that with a smaller impact allowance which would occur on the bridge when it is new the total of load plus impact should not be less than that for which the bridge is designed.

Measurements of deflection are also generally taken and compared with the calculated deflections. It is impossible to express this in terms of any simple formula, and it will of course vary with the construction and type of bridge.

The Thickness of Reinforced Concrete Slabs.

In the design of reinforced concrete members which are subjected to bending one determines the position of the neutral axis and the thickness of slab from a knowledge of the moment of the exterior forces acting on the member. Unfortunatley this moment is only known exactly when we know the slab thickness, so that it is necessary to assume a slab thickness in order to find the moment. This method of trial and error is likely to be a cause of much wasted time by young designers, and M. A. Merciot has recently given, in *Le Constructeur de Ciment Armé*, a method which avoids all guesswork about the weight of the slab. This method may be applied to slabs of any degree of fixity at their ends. M. Merciot assumes freely supported ends in his calculation, which we reproduce here.

Take a slab of 1 metre width and *el* metres span.

Let p = wt. of 1 sq./m. of slab.

p^1 = wt. of superload on 1 sq. m. of slab.

M_p and M_s the corresponding bending moments at the centre of the span.

Then,
$$M_p = \tfrac{1}{8}p.l^2 \text{ and } M_s = \tfrac{1}{8}p^1.l^2.$$

Also,
$$\frac{M_p}{M_s} = \frac{p}{p^1}$$

and
$$(M_p + M_s) = M_s\left(\frac{M_p}{M_s} + 1\right) = M_s\left(\frac{p}{p^1} + 1\right).$$

Let h_s = effective depth of a slab carrying p^1 *only*.

h_p = ,, ,, ,, ,, p *only*.

Then the total effective depth is
$$H = h_s + h_p$$

Now $h_s + h_p = \beta\sqrt{\dfrac{M_s + M_p}{b}}$, where β is a coefficient and b = width of slab = 1 metre.

$$\therefore\ h_s + h_p = \beta\sqrt{M_s + M_p}.$$

$$\therefore\ h_s^2 + 2h_sh_p + h_p^2 = \beta^2 M_s\left(\frac{M_p}{M_s} + 1\right),$$

but
$$\frac{M_p}{M_s} = \frac{p}{p^1} \text{ and } h_s + h_p = \beta\sqrt{M_p + M_s}$$

$$\therefore\ h_s^2 = \beta^2 M_s$$

$$\therefore\ \frac{h^2_p}{h_s^2} + 2\frac{h_p}{h_s} = \frac{p}{p^1}.$$

Make $\dfrac{h_p}{h_s} = K$ and we get, $K^2 + 2K = \dfrac{p}{p^1}$.

But p = wt. of 1 sq. m. of slab of a total thickness = $h_s + h_p + d^1$, where d^1 = distance of tension steel above bottom of slab.

If Δ = wt. of 1 metre cube of concrete in kg.

$$p = \Delta(h_s + h_p + d^1) = \Delta h_s\left(K + \frac{d^1}{h_s} + 1\right)$$

$$\therefore\ K^2 + 2K - \frac{\Delta h_s}{p^1}\left(K + \frac{d^1}{h_s} + 1\right) = 0,$$

or,

$$K^2 + K\frac{2p^1 - \Delta h_s}{p^1} - \frac{\Delta h_s}{p^1}\left(\frac{d^1}{h_s} + 1\right) = 0.$$

This equation gives K and $h_p = Kh_s$.

Numerical Example.

Span = 2 metres; superload = 500 kg.
$d^1 = 2$ cm. Concrete stress = 50 kg. per cm².
Steel stress = 1,200 kg/cm².

Here

$$M_s = \frac{500 \times 2^2}{8} = 250 \text{ kg. m.}$$

$$h_s = 0{\cdot}346\sqrt{250} = 5{\cdot}37 \text{ cm.}$$

$$\frac{d^1}{h_s} + 1 = 1{\cdot}37$$

$$\frac{\Delta h_s}{p^1} = \frac{2400 \times {\cdot}0537}{500} = 0{\cdot}2578$$

$$K^2 + 2K - 0{\cdot}2578(K + 1{\cdot}37) = 0$$

or,

$$K^2 + 1{\cdot}74K - 0{\cdot}35 = 0$$

$$\therefore\ K = 0{\cdot}18$$

$$h_p = 0{\cdot}18h_s = 0{\cdot}18 \times 5{\cdot}37 = 9{\cdot}6 \text{ mm.}$$

Total depth of slab $= h_s + h_p + d^1$
$= 5{\cdot}37 + 0{\cdot}96 + 2 = 8{\cdot}33$, say 9 cm.

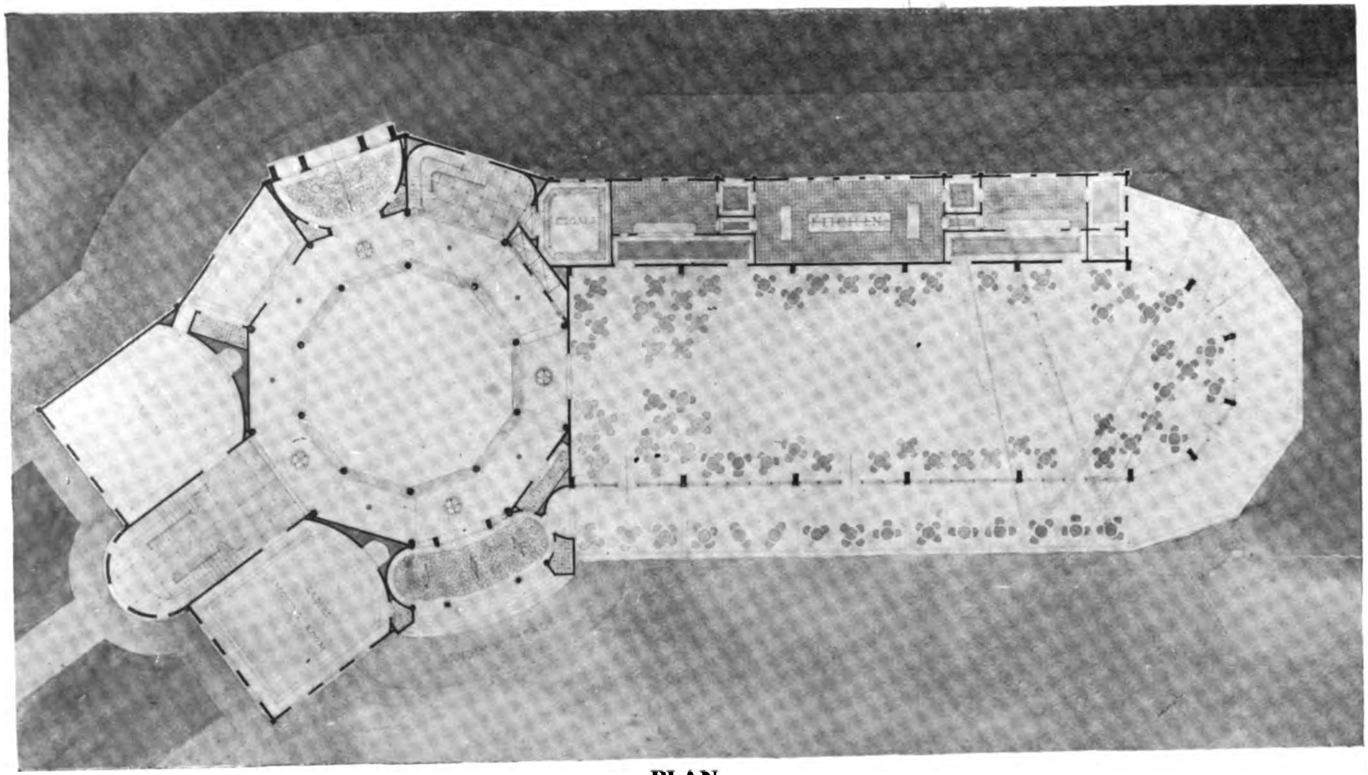
CHECK.—The dead wt. of a 9 cm. slab is 216 kg. Therefore the total load is (500 + 216) kg. = 716 kg.

And the total depth of the slab is $H^1 = 2 + 0{\cdot}346\sqrt{\frac{716 \times 4}{8}} = 8{\cdot}6$, say 9 cm.—W. S. G.

Essay Competition.

THE organizers of the Public Works, Roads and Transport Congress and Exhibition are offering medals and money prizes for papers to be read at the Congress in November 1927. Full particulars may be obtained from the Honorary Secretary of the Congress, 84 Eccleston Square, S.W.1.

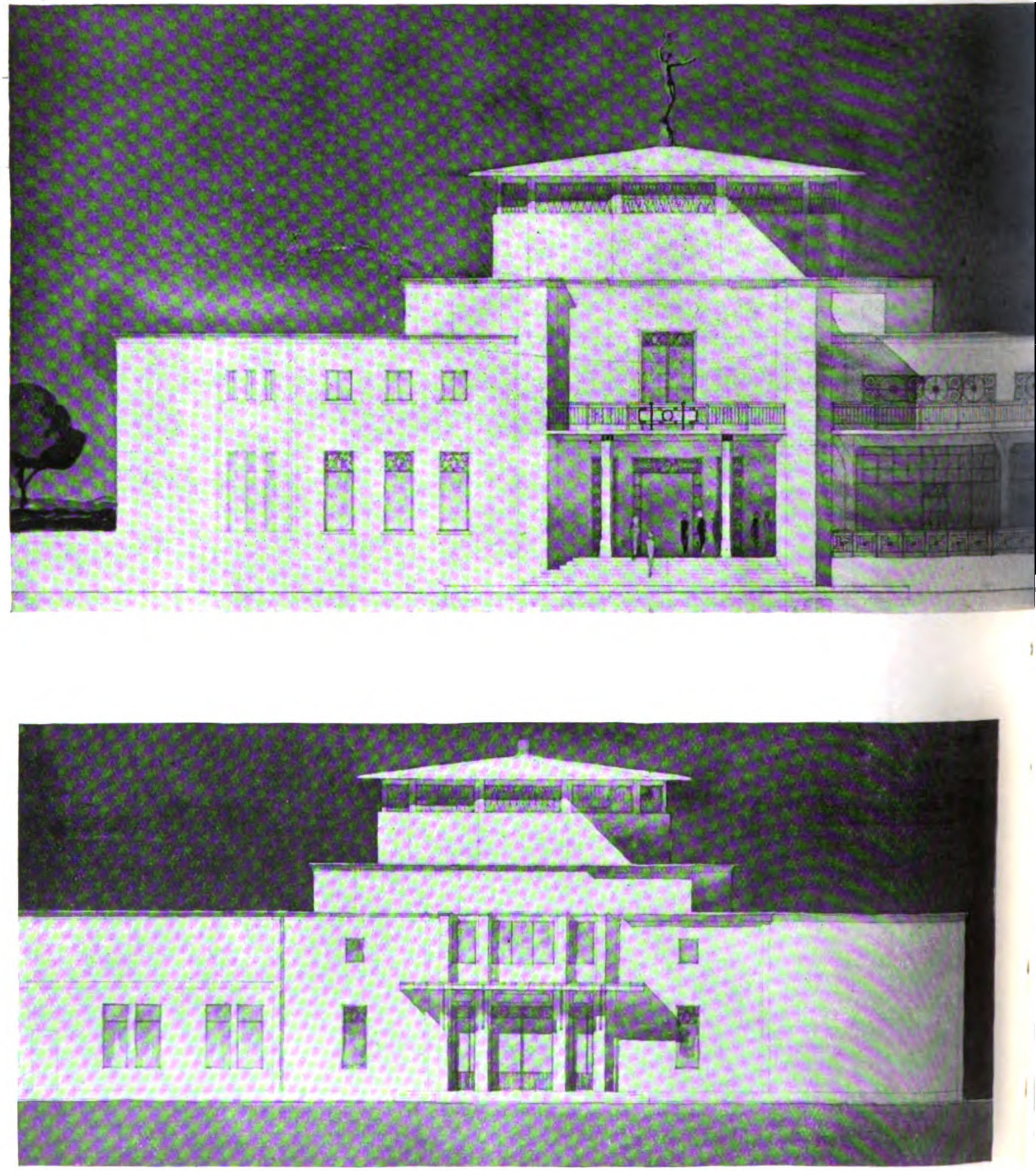
"Concrete and Constructional Engineering" Prize Design.



PLAN.

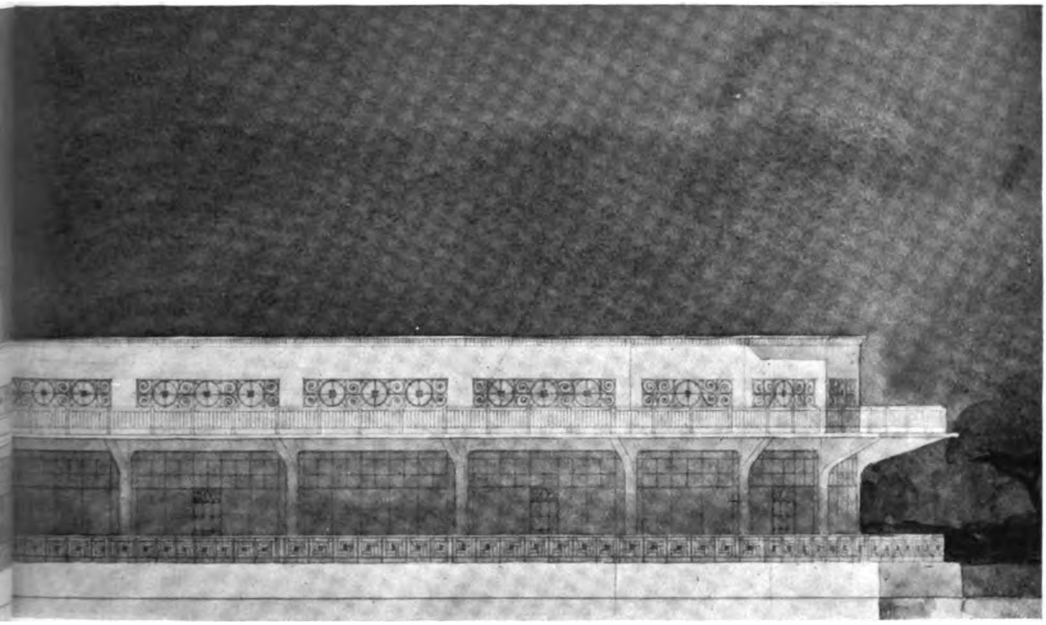
A Reinforced Concrete Pavilion on the Serpentine. Prize Design, by Miss Jessie M. Greig (London University School of Architecture). (*See p.* 554.)

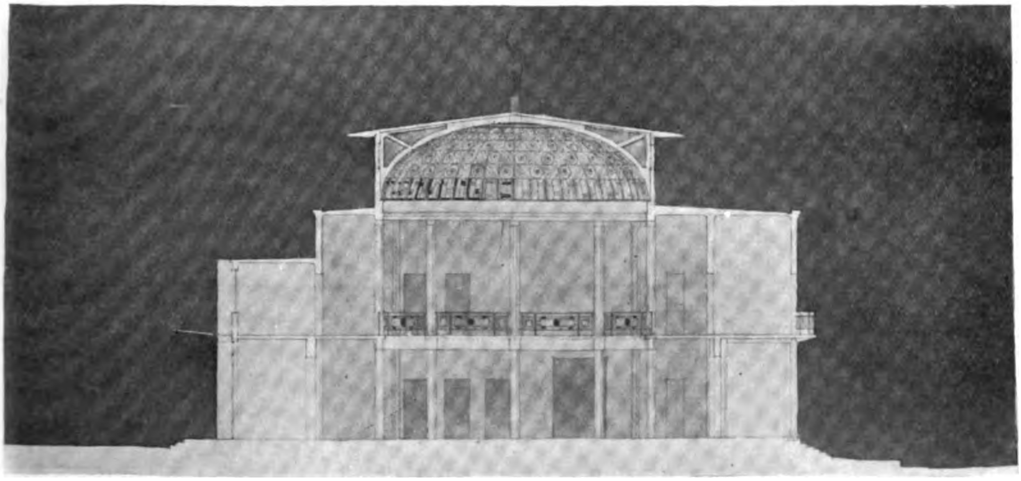
“Concrete and Constructiona



A REINFORCED CONCRETE PAVILION ON THE SERPENTINE
of Architecture.

l Engineering" Prize Design.





Prize Design, by Miss Jessie M. Greig (London University School
(*See p.* 541.)

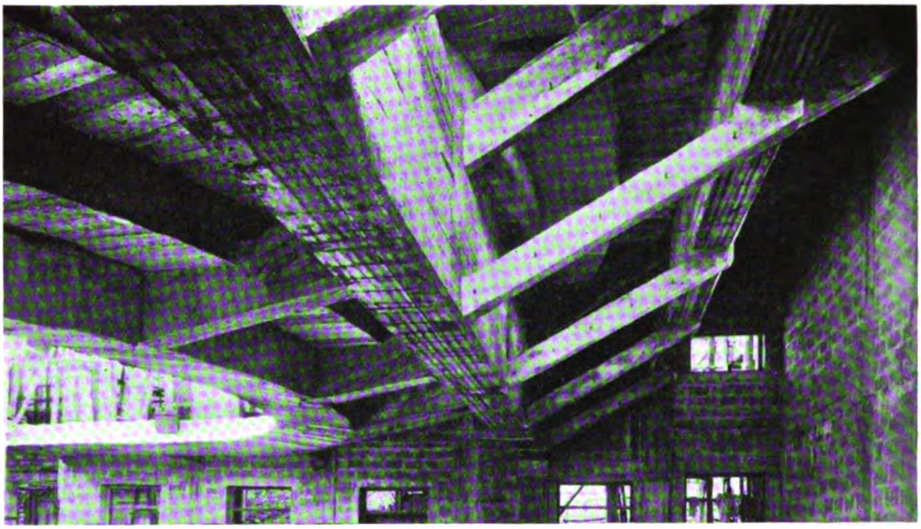


Fig. 3.—Charni Road Theatre, Bombay: Main Beams under Gallery.

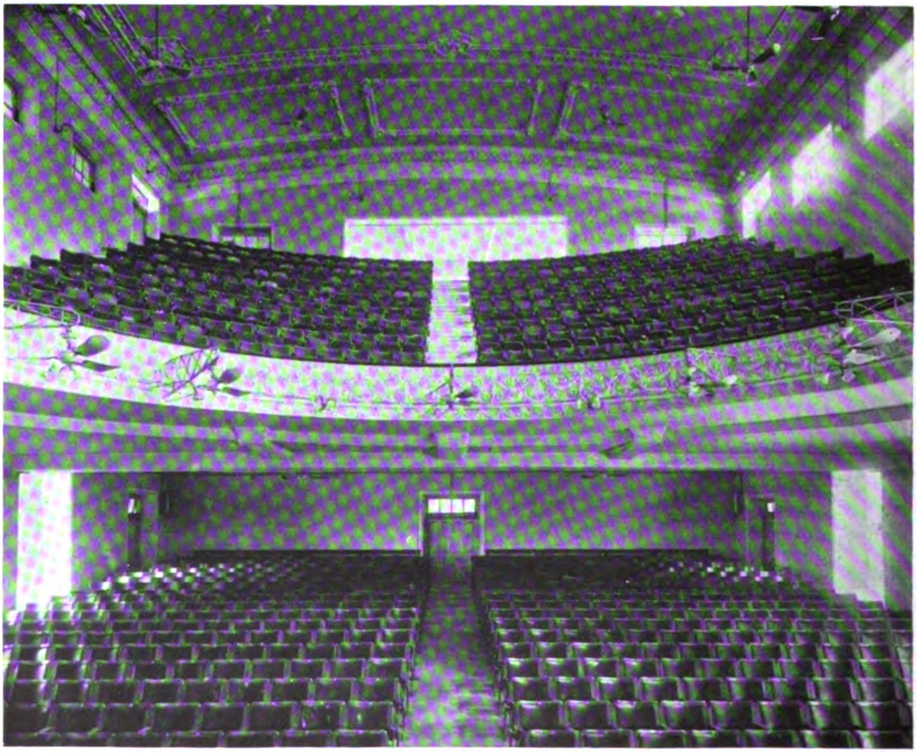


Fig. 4.—Ripon Theatre, Bombay: View from Stage.

Reinforced Concrete in India.

Two Theatres in Bombay.

By R. P. MEARS, M.Inst.C.E.

THE Charni Road Theatre has recently been built by Messrs. J. C. Gammon, Ltd., reinforced concrete engineers and contractors, of Bombay, to the designs and under the general direction of the architects, Messrs. Merwanjee, Bana & Co., of Bombay. All details of reinforcement were prepared by the contractors.

Fig. 2 shows the outside elevation, which is constructed entirely of pre-cast concrete blocks. *Fig.* 1 is a view from the stage showing the seating accommodation and two galleries. It will be noted that there are no obstructing columns.

Fig. 3 is a view taken during construction under the main gallery, showing the main beams of 50-ft. span. The reinforcement of these heavy beams consists of 16 bars of 1½ inch diameter, both top and bottom, for bending moment, as well as heavy shear steel. These long lengths of bars had to be specially imported. Props were kept up for two months, and when withdrawn and the beam loaded no deflection or set was measurable.

The same firms of architects and reinforced concrete contractors constructed the Ripon Theatre, Bombay, an interior view of which is shown in *Fig.* 4.

The interior construction is very similar to that of the Charni Road Theatre. *Fig.* 5 shows the gallery beams of 55-ft. span. These beams contain 24 bars of 1½ in. and 1 in. diameter top and bottom, which also, owing to their length, had to be specially imported. In this instance the main walls are of brick, but specially designed reinforced concrete columns support the ends of these heavy beams.

In these buildings, as in all others carried on under a cloudless sky and a tropical sun frequently accompanied by

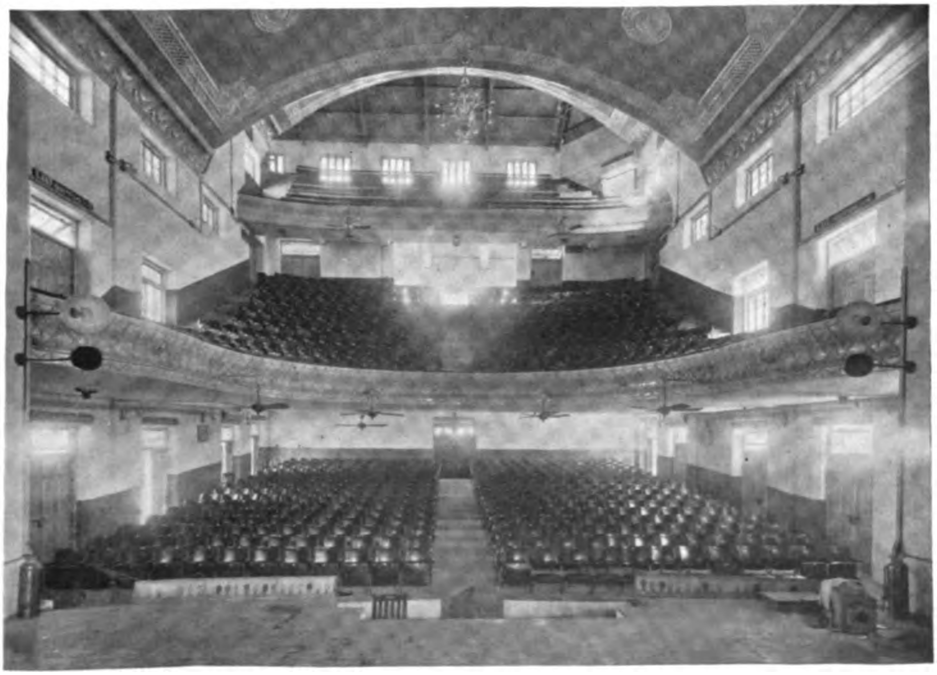


Fig. 1.—Charni Road Theatre, Bombay: View from Stage.

a hot dry wind, very great precautions are necessary in order that concrete shall not dry out too quickly. *Fig.* 6 shows a typical job wherein the *mutti bunds* and water on the newly laid concrete floors can be seen, with leaking water-pots on the tops of newly-filled columns. The temporary clothing of these columns is also visible; this retains the moisture and wards off the effects of sun and wind. This picture also shows good centering and well-laid reinforcement. Ready mixed concrete is being carried in steel *ghamillas* on the heads of coolie women, while masons and well-trained coolies do the depositing and ramming. Mixing is

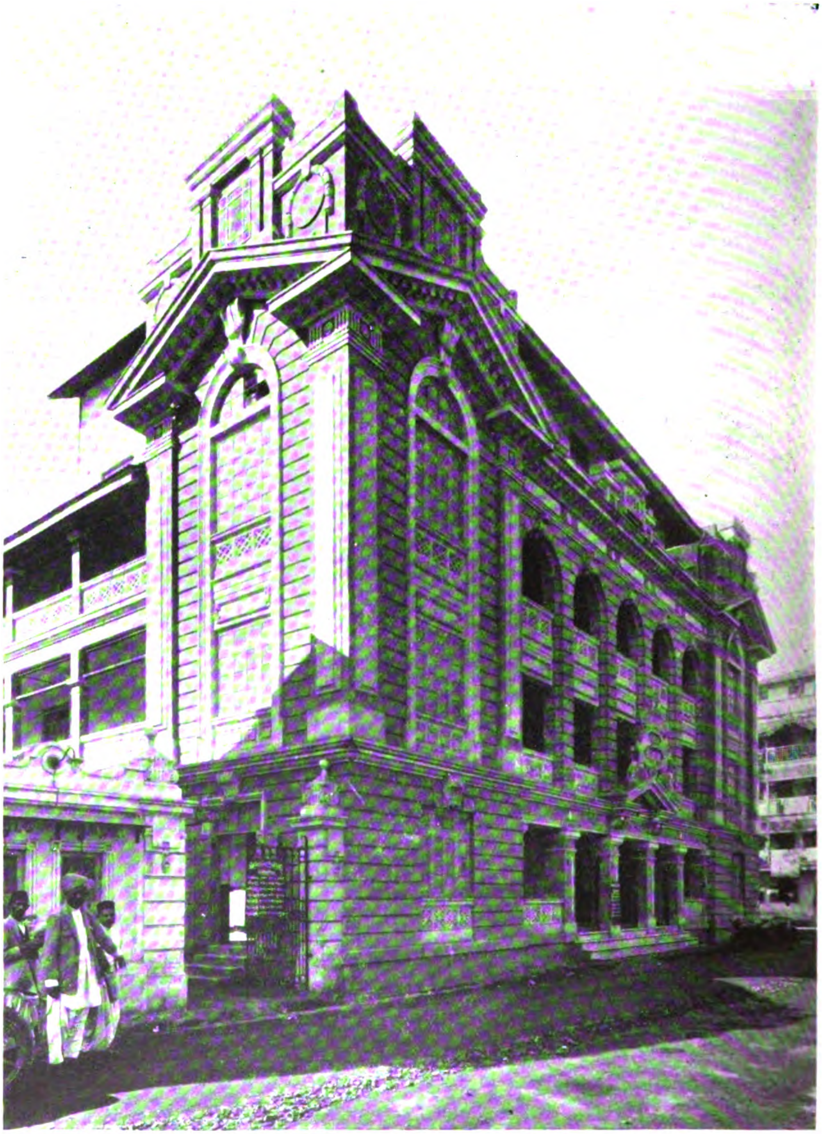


Fig. 2.—Charni Road Theatre, Bombay.

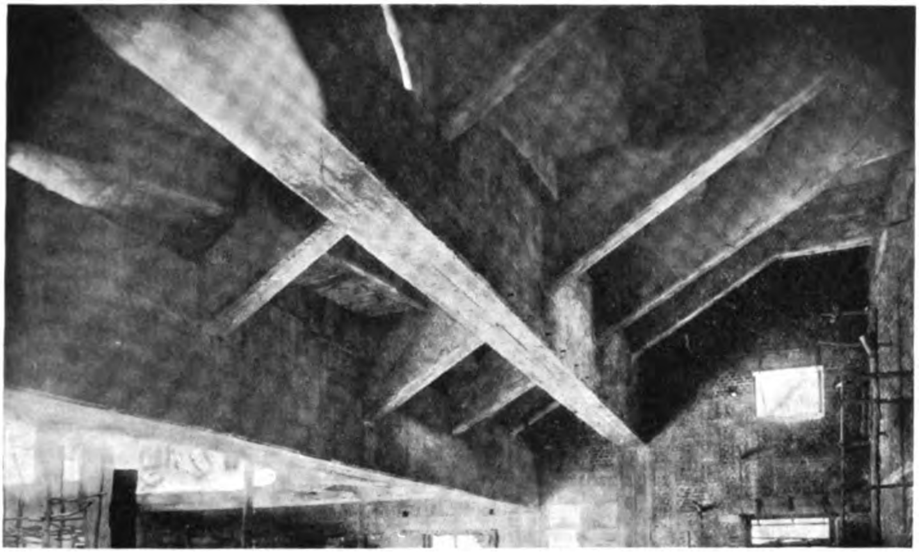


Fig. 5.—Ripon Theatre, Bombay: Main Beams under Gallery.

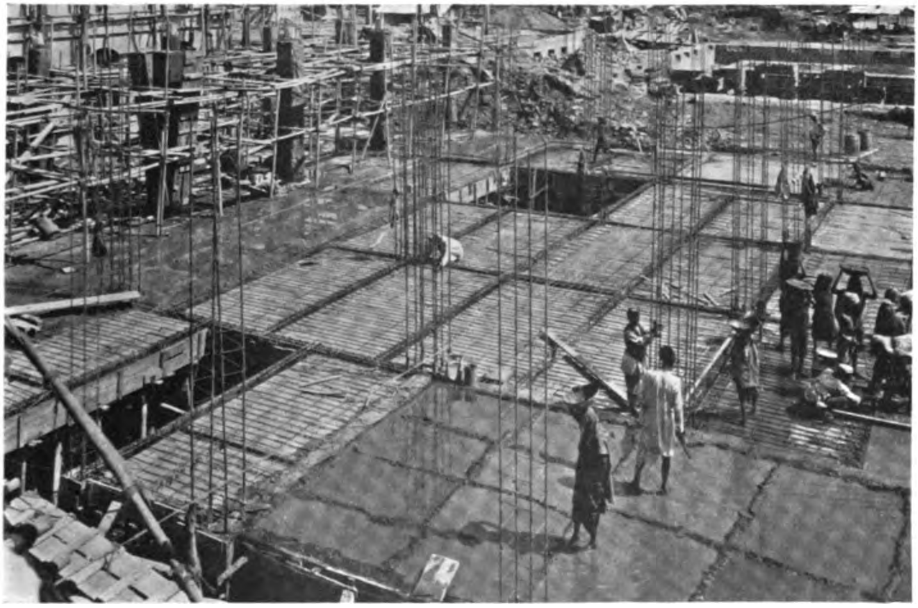


Fig. 6.—Method of Protecting Concrete during Hardening.

usually done by machine as at home, but hoists and chutes are not regularly used in a land where unskilled labour is cheap and generally plentiful, while machinery may generally be said to prove expensive in upkeep and maintenance as well as more expensive than at home due to its imported price.

The author has known of instances at home during the summer when contractors would be well advised to adopt some of the curing precautions shown in these pictures. Keeping concrete damp for two or three days by means of a hose will not compare with the benefits derived from keeping 2 in. of water over a newly-laid floor for a fortnight—a few hours of hot sunshine accompanied by a dry wind can utterly spoil a lot of good concrete when " green." Dense and well-graded concrete, well-rammed, obviously containing all the specified cement, and yet being capable of being broken up in the hands of the inspector, is a very sad experience. The cement is generally the first ingredient to be blamed, but other work done with the same consignment and brand of cement causes one to look elsewhere for the cause of the trouble. Attempts follow to show chemical reactions between the sand and cement, etc., but the fact of such failure of concrete to harden and become strong is very frequently nothing more nor less than insufficient watering during the curing stage. It may further be noted that watering cannot be overdone, for is not the best concrete found in concrete reservoirs where the material is always under water ?

Recent Patent Applications.

228,538.—N. C. Johnson : Treatment of concrete surfaces.
233,698.—U. B. Voisen : Process for the manufacture of aluminous cement.
237,860.—K. J. Ljunberg : Reinforced-concrete structures.
239,163.—R. Williams : Centrifugally moulding concrete pipes.
250,993.—J. W. Laing : Concrete houses.
251,042.—B. Morton : Shuttering for concrete structures.
251,378.—C. E. P. Sankey : Shoes for concrete piles.
251,823.—R. Pearce : Shozing for concrete man-holes.
252,465.—L. Anwyn : Concrete blocks.
252,583.—C. Westphal and R. Grieger : Building with concrete.
252,780.—G. E. Heyl : Cement and lime burning.
252,975.—A. G. Ratinoff : Reinforced concrete.
253,007.—Broadway Trust Co. Ltd., C. D. Burney and J. E. Temple : Light forms of concrete or artificial wood.
253,222.—D. H. Stent : Concrete walls.
253,330.—W. Wilson : Faced or ornamental concrete.
253,589.—F. J. Lee and C. Fouracre : Machine for moulding concrete.
253,647.—W. P. Stanton : Hollow concrete building-blocks.
253,706.—J. Cramer : Shuttering.

New Companies Registered.

Monolithic Building Co., Ltd. (214571). Registered June 23. To erect concrete and other houses and buildings ; to acquire from Monolithic Concrete Houses, Ltd., an exclusive licence to use the British patent and the Edison-Duncan system of poured concrete construction, and the shares in the Condual Construction Co., Ltd. Nominal capital : £1,050.

Reinforced Cement Corrugated Sheet Co., Ltd. (214876). To carry on the business as indicated by the title. Registered July 7. Nominal capital : £6,000. Permanent directors : A. Batchelor, Bleak House, Broadstairs ; J. W. R. Wright, " St. Quintin," First-avenue, Gillingham ; A. H. J. Wright, " St. Quintin," First-avenue, Gillingham.

Expansion of Concrete, with Special Reference to Concrete Tanks.

By W. H. GLANVILLE, B.Sc., A.M.Inst.C.E.

(*Building Research Station.*)

EXPANSIONAL movements in concrete result from two causes, namely, temperature variations and moisture variations. Although it is customary in the design of most concrete structures to ignore any stresses that result from these movements, there are certain special cases in which the material is seriously constrained and stresses of considerable magnitude may occur. One such case has recently come to the notice of the Building Research Station, and it is the object of the present paper to throw some light upon the magnitude of the stresses involved and at the same time to make a permanent record of the experimental results obtained in the process of analysing the problem.

The temperature expansions, provided no drying action takes place, are practically equal for concrete and steel, so that if the temperature is uniform throughout a particular structure and there is no external constraint, a temperature change will not set up stresses in the materials.

The movements due to moisture changes are, however, more complex, and any stress distribution is further complicated by the fact that the moisture condition affects only the concrete and not the steel. Measurements taken over many years have proved that concrete stored in air shows a continuous decrease in dimensions, whereas concrete kept in water exhibits a continuous increase, in both cases the action proceeding at a decreasing rate. Moreover, if at any time the conditions of storage be varied, the concrete will adjust itself to the new conditions ; if dried it will contract, and if wetted it will expand. Typical curves taken from " Einfluesse auf Beton " (Kleinlogel, 1925) are given in *Fig.* 1. Moisture also tends to render concrete impermeable, so that even though a concrete may be wetted on one face only, and the water may at first permeate throughout the mass and cause the whole material to expand uniformly, the concrete will rapidly become less permeable until eventually the moisture will penetrate for a short distance only below the wetted surface, and moisture expansion will only be effective over this distance. It is evident, therefore, that a complicated system of internal stresses may be set up in any concrete or concrete structure by differential expansions due to variations in moisture condition.

The particular example of construction to which it is desired to draw attention in this paper is that of certain concrete tanks used for the storage of water at temperatures up to boiling point. The concrete under conditions such as these is subjected both to a heat gradient and a moisture gradient, each tending to produce greater expansion on the internal than the external face. Additive stresses are consequently set up, giving compression internally and tension externally.

The temperature conditions are extreme, and it will be shown that, although the stresses set up by moisture alone (on the assumption that the moisture expansion gradient is of the same form as the heat gradient) may be of considerable magnitude, in the case under consideration they do not approach in value those due to temperature.

The tanks, which were small and therefore comparatively unaffected by the head of the contained water, were cracked in the manner shown in *Fig.* 2, the distribution of cracks being the same whether the walls were reinforced or not or whether composed of Portland cement or of high-aluminous cement concrete. The cracking occurred on the first heating of the contained water, and was not therefore due to any cumulative shrinkage or swelling of the concrete. The concrete used was of good quality, carefully gauged and mixed to 1 : 2 : 4 proportions, and would, in normal conditions, have proved an impermeable product.

In order to make even an approximate stress analysis it was necessary to know the following expansion coefficients for concrete :—

(*a*) The expansion due to temperature only.

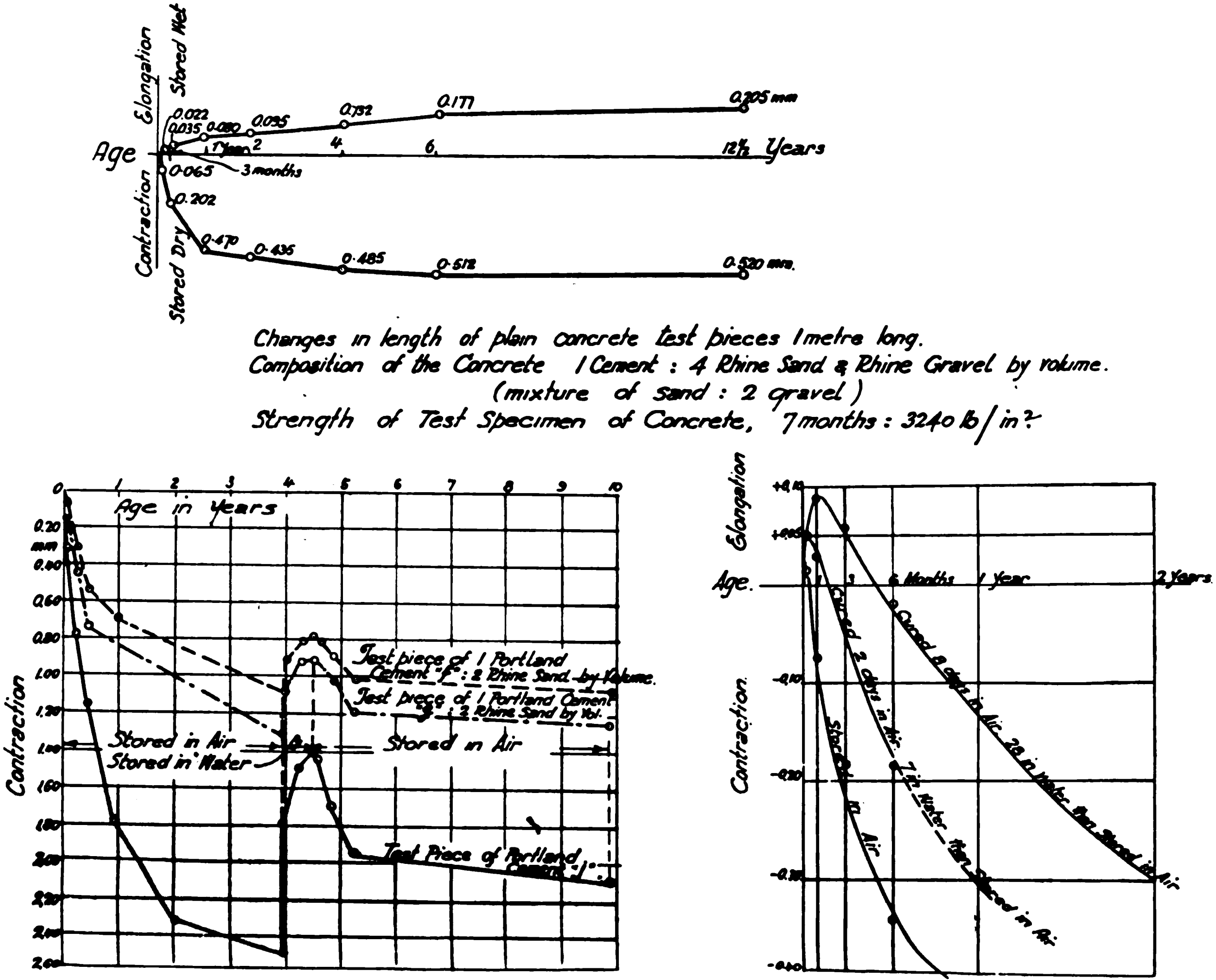


Fig. 1. Typical Moisture Expansions.

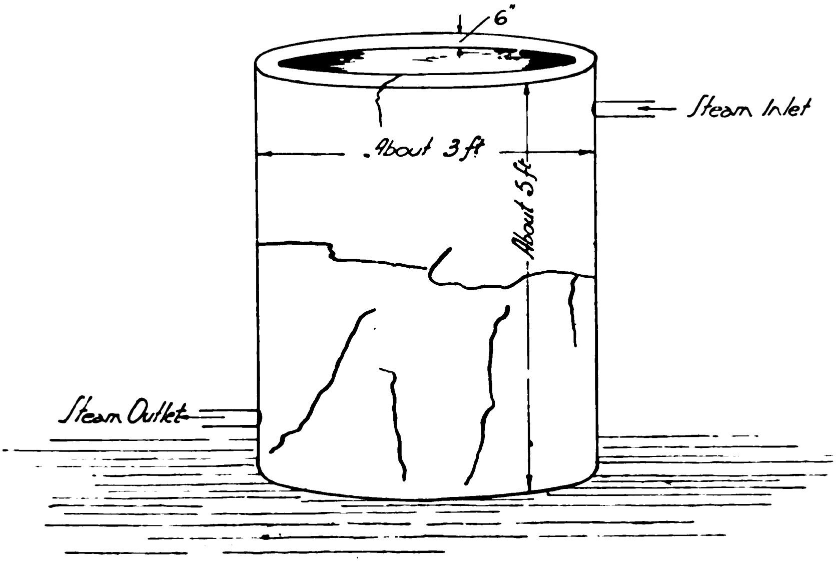


FIG. 2.

DIAGRAM OF TANK.

(*b*) The expansion due to moisture only.

(*c*) The expansion due to combined temperature and moisture.

So far as the writer was able to ascertain there were no figures available for the combined moisture and temperature expansions, and it was decided to measure all three expansions and to examine the relations existing between them.

The apparatus employed for this purpose is represented diagrammatically in *Fig.* 3. It consists of a small three-legged rocking lever A, two legs of which are supported on external silica rods, while the third and moving leg rests on a central silica post D fixed to the top of the specimen under test. A mirror attached to the rocking lever enables optical magnification of about 1,500 to be obtained with a suitable telescope and scale. The use of silica rods obviates the necessity for applying an apparatus temperature correction. The apparatus is enclosed in a tank to permit immersion of the specimen, and temperature control is obtained by means of a steam coil.

Figs. 4, 5, and 6 are typical curves showing temperature expansion, moisture expansion, and combined moisture and temperature expansion respectively. The specimens tested were not thoroughly dried out before testing, but were taken straight from air or water storage in the laboratory. In the determination of the coefficients of heat expansion for dry specimens the specimen was taken up to the maximum temperature and allowed to cool down slowly. During the process of heating a certain amount of moisture was evaporated from the specimen so that the expansion recorded was a combination of the heat expansion and the contraction due to this loss of moisture. This is shown in *Fig.* 4, the falling off from the straight line from *b* to *c* being due to the loss of moisture. The residual contraction shown is entirely due to loss of moisture. The coefficients of expansion given in the Table are taken from the cooling curves in order to eliminate this effect as far as possible.

In the determination of the combined moisture and temperature expansions a similar residual expansion due to moisture was recorded at the conclusion of the experiment (see *Fig.* 5).

An examination of the tabulated results reveals several points of interest, which may be summarised as follows :—

(1) Under the conditions of these ex-

TABULATION OF RESULTS.

Specimen No.	Mix. Proportions by weight.	Age when tested, days.	Curing.	Expansion measured.	Description of Tests.	Coefficient of Expansion (per °C. from Cooling curve) $\times 10^{-5}$	Residual Expansion per unit length $\times 10^{-5}$.	Moisture change by weight.	Remarks.
M.17	1 : 2 : 4 Portland Cement	24	Air	Heat	Heated in air to about 40° C. in 6 hrs. Kept at this temp. for 18 hrs. and cooled in 6½ hrs.	1·07	—3·2	— 0·31	Fig. 3 shows the curves from this test. The bend (*bc*) is due to drying out.
M.13	1 : 2 : 4 Portland Cement	22	Air	Heat	Heated in air to 50° C. in 5 hrs. Kept at this temp. for 1 hr. and cooled gradually overnight.	1·03	—	—	—
70	1 : 2 : 4 Portland Cement	28	Air	Moisture	Immersed in water for 48 hrs.	—	11·0	3·59	—
M.22	1 : 2 : 4 Portland Cement	28	Air	Moisture	Immersed in water for 48 hrs.	—	5·1	—	—
M.14	1 : 2 : 4 Portland Cement	23	Air	Moisture and Heat	Immersed in water and raised to 95° C. in 3 hrs. Kept at this temp. for 1½ hrs. and cooled gradually overnight.	1·26	10·0	3·45	—
M.15	1 : 2 : 4 Portland Cement	24	Air	Moisture and Heat	Immersed in water and raised to 95° C. in 1½ hrs. Kept at this temp for 1 hr. and cooled in 3 hrs.	1·16	12·5	—	—
	1 : 2 : 4 Ciment Fondu	About 6 months	Air	Moisture and Heat	Immersed in water and raised to 95° C. in 3 hrs. Kept at this temp. for 1 hr. and cooled gradually overnight	1·21	14·9	2·53	—
M.2	1 : 2 : 4 Portland Cement	31	Water	Moisture and Heat	Immersed in water and raised to 95° C. in 3 hrs. Kept at that temp. for ½ hr. and cooled gradually overnight.	1·23	—	0·12	—
M.1	1 : 2 : 4 Portland Cement	28	Water	Moisture and Heat	Immersed in water and (*a*) raised to 95° C. in 2 hrs. Kept at this temp. for 1 hr. and cooled in 1 hr.	1·13	19·0	—	Surface of specimen badly cracked, probably due to rapid cooling, this accounts for big residual expansion.
					(*b*) raised to 95° C. in 1½ hrs. Kept at this temp. for 3 hrs. and cooled in 2 hrs.	1·14	9·4	—	
					(*c*) Raised to 95° C. in 1½ hrs. Kept at this temp. for 3 hrs. and cooled overnight.	1·18	—	0·52	

Average coefficient of Expansion Dry Heat, 1·05 × 10^{-5} per °C. (2 specimens).
,, ,, ,, ,, ,, ,, 1·20 × 10^{-} per °C. (4 specimens).

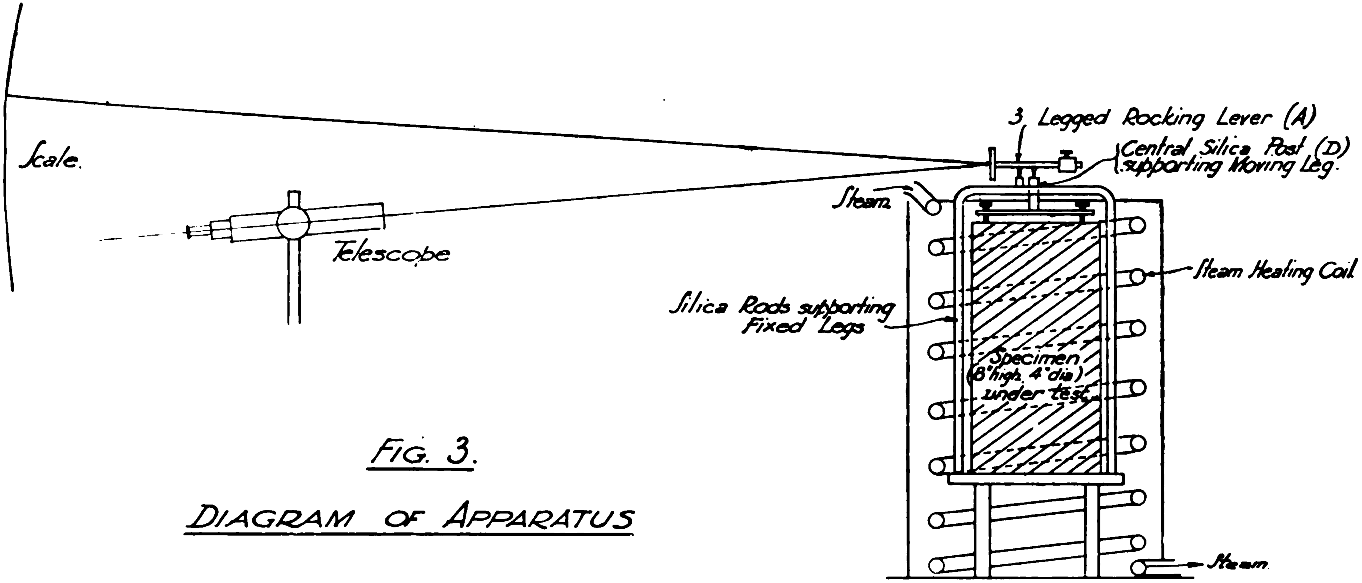

3 Legged Rocking Lever (A)
Central Silica Post (D) supporting Moving Leg.
Scale.
Steam
Telescope
Steam Heating Coil
Silica Rods supporting Fixed Legs
Specimen (8" high. 4" dia) under test.
Steam

FIG. 3.

DIAGRAM OF APPARATUS

periments the coefficients of expansion due to temperature appear practically the same whether the concrete is immersed in water or not. The actual average figures show a difference of about 15 per cent., but the number of experiments conducted does not justify the drawing of a final conclusion.

(2) When a specimen which has been cured in air is heated in water to 95° C. and then allowed to cool to its original temperature it does not return to its initial length. The amount by which it has expanded (the residual expansion) is of the same order as the moisture expansion obtained by immersion without heating (compare *Figs.* 5 and 6).

(3) Both the moisture expansion obtained by immersion in water for 48 hours (of a specimen initially at moisture conditions in equilibrium with the air of the laboratory) and the residual expansion after heating in water are equivalent to the expansion due to a rise in temperature of about 10° C.

(4) High-aluminous cement concrete behaves in the same manner as Portland cement concrete. There is no appreciable difference between either the coefficients of temperature expansion or the coefficients of moisture expansion.

(5) The rate of heating, within the limits of the experiments, has no measurable influence on the expansion, except when cooling or heating is so rapid that the stresses set up cause cracking in the specimen.

(6) The coefficients of temperature

FIG. 4. HEAT EXPANSION IN AIR

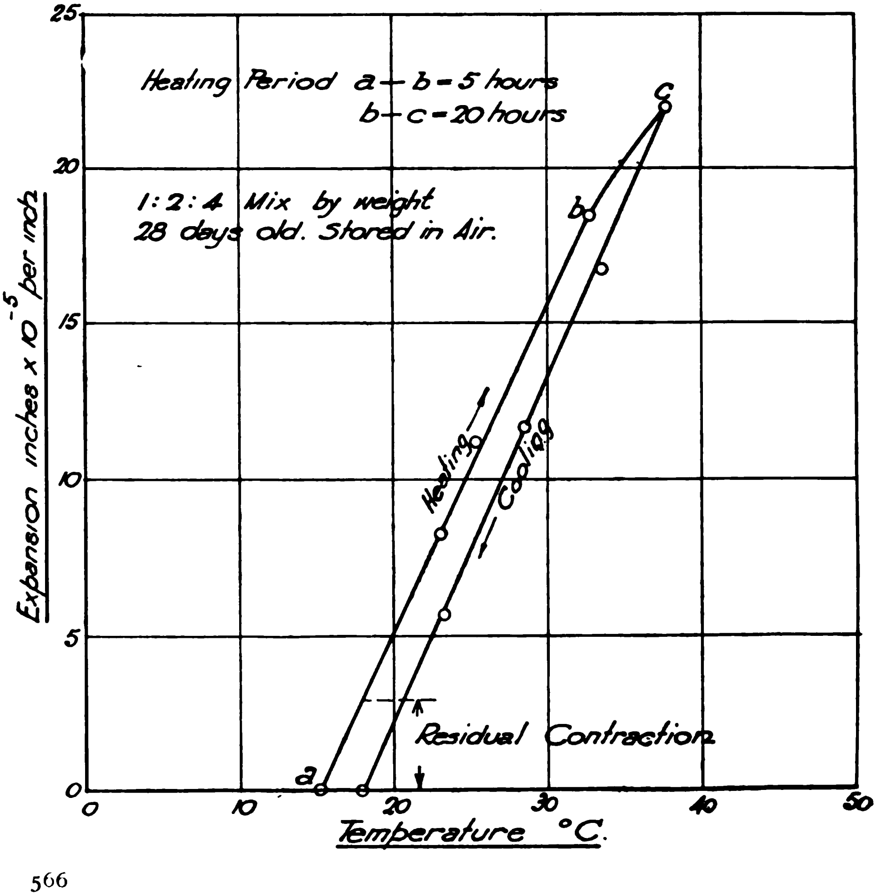
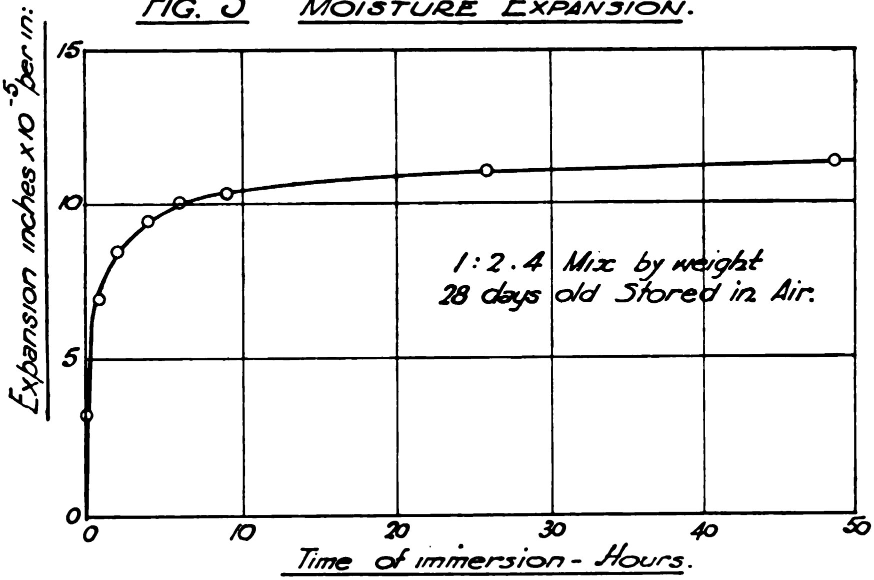


FIG. 5 MOISTURE EXPANSION.



expansion, taken from the cooling curves, are the same for water stored and air stored concrete.

In order to calculate the stresses involved it is necessary to know both the moisture (more strictly, moisture expansion, since the amount of moisture expansion depends also on time) and temperature gradients through the walls of the tanks. At the present stage of our knowledge of the laws governing the absorption of water by concrete it is impossible to give any figures for the former, and it becomes necessary in order to make any calculation at all to make some assumptions. The temperature gradient can be taken as that obtained from the usual laws of heat conduction and it is convenient to consider the moisture distribution as equivalent to a temperature gradient set up by a difference between the inner and outer faces of 10° C., this difference being the equivalent obtained by experiment for 48 hours' immersion. In any case the elastic constants for concrete vary within wide limits and calculations must necessarily be only very approximate.

The theory of the stresses in a hollow cylinder subjected to a heat gradient has received attention from several investigators, each of whom has reached, independently, approximately the same conclusions.. The most recent publication on the subject is that by Letson & Lamb.* The assumptions made are that the material is homogeneous and isotropic as regards its thermal and elastic properties, and that the point under consideration is sufficiently distant from the free ends to permit the end effects to be ignored. It is obvious that none of these assumptions is perfectly justifiable in the case of concrete tanks, but, as a first approximation, it is interesting to examine the magnitude of the stresses obtained.

The temperature stresses alone will first be considered. The actual temperatures measured on the tanks were 100° C. internally and 60° C. externally; these temperatures will be used in the calculations. The formulæ as given by Letson and Lamb are as follows:—

$$p_a = q_a = \tfrac{1}{2}\frac{\alpha(\theta_a - \theta_b)E}{1 - \sigma}\left(\frac{1}{\log\frac{b}{a}} - \frac{2b^2}{b^2 - a^2}\right)$$

---

* "Thermal Effects in Diesel Engine Liners," *Proc. Inst. Mech. Eng.*, January, 1925. An appendix to this paper gives a method of determining the stresses for any temperature distribution whatever, a method which could of course be equally well applied to any moisture distribution if this were known.

and

$$p_b = q_b = \frac{1}{2}\,\frac{\alpha(\theta_a - \theta_b)E}{1 - \sigma}\left(\frac{1}{\log\frac{b}{a}} - \frac{2a^2}{b^2 - a^2}\right)$$

where

p = tangential stress.
α = coefficient of heat expansion.
a = internal radius.
E = modulus of elasticity.
q = longitudinal stress.
θ = temperature.
b = external radius.
σ = Poisson's ratio.

the subscripts *a* and *b* referring to internal and external radii respectively. Taking the values relevant to the actual tanks as :—

$\alpha = 11 \times 10^{-6}$ per ° C.
$\theta_b = 60°$ C.
$\sigma = 0{\cdot}1$
$\theta_a = 100°$ C.
$E = 2 \times 10^6$ lb./sq. in.
$a = 18''$
$b = 24''$.

we have by substitution in the formulæ

$p_a = q_a = -530$ lb./sq. in. compression on the internal face.

$p_b = q_b = +440$ lb./sq. in. tension on the external face.

(*Continued on p.* 572.)

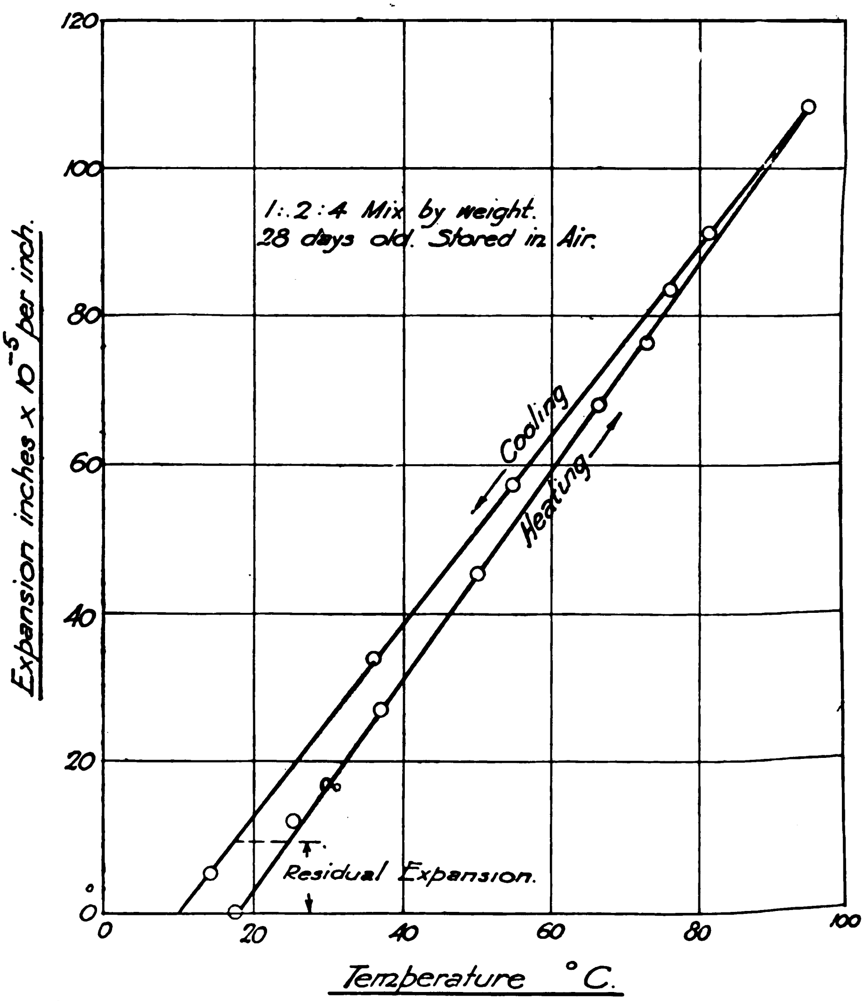
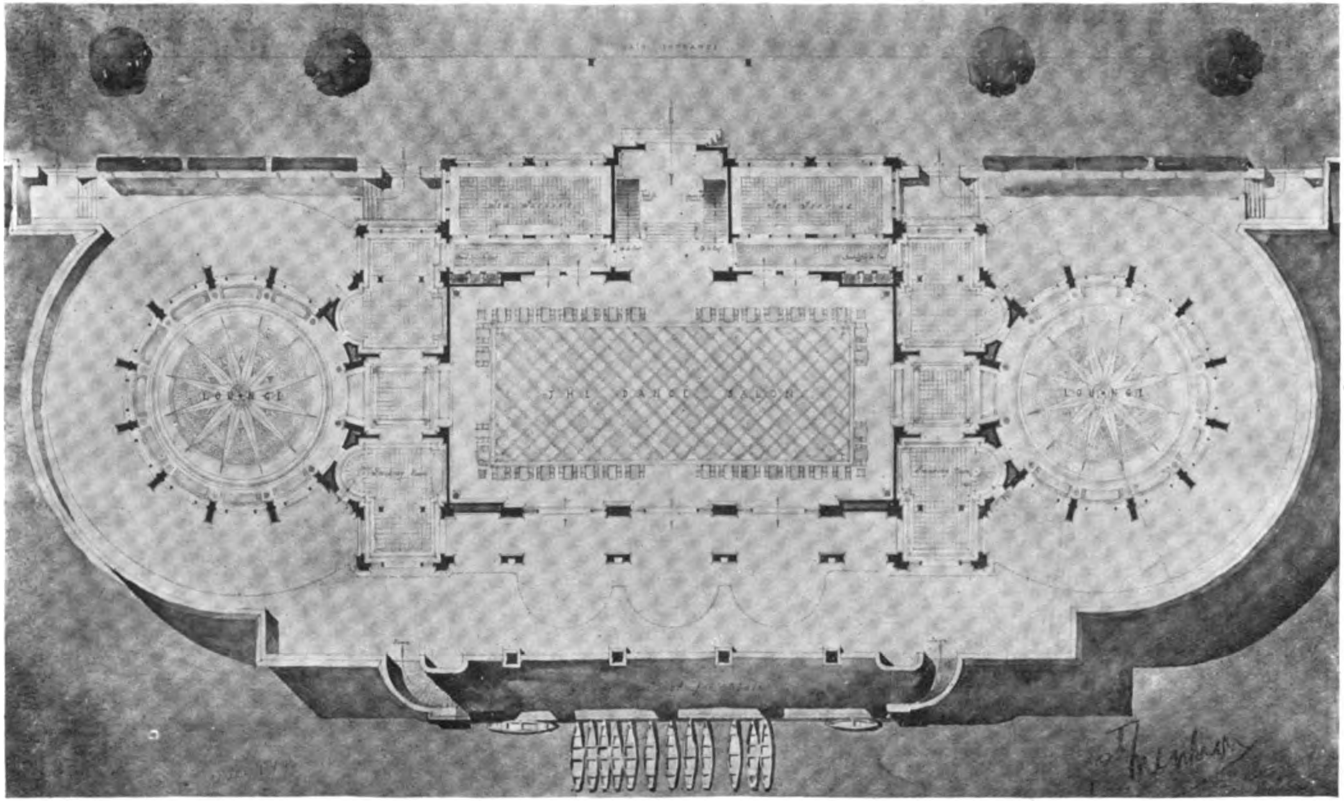


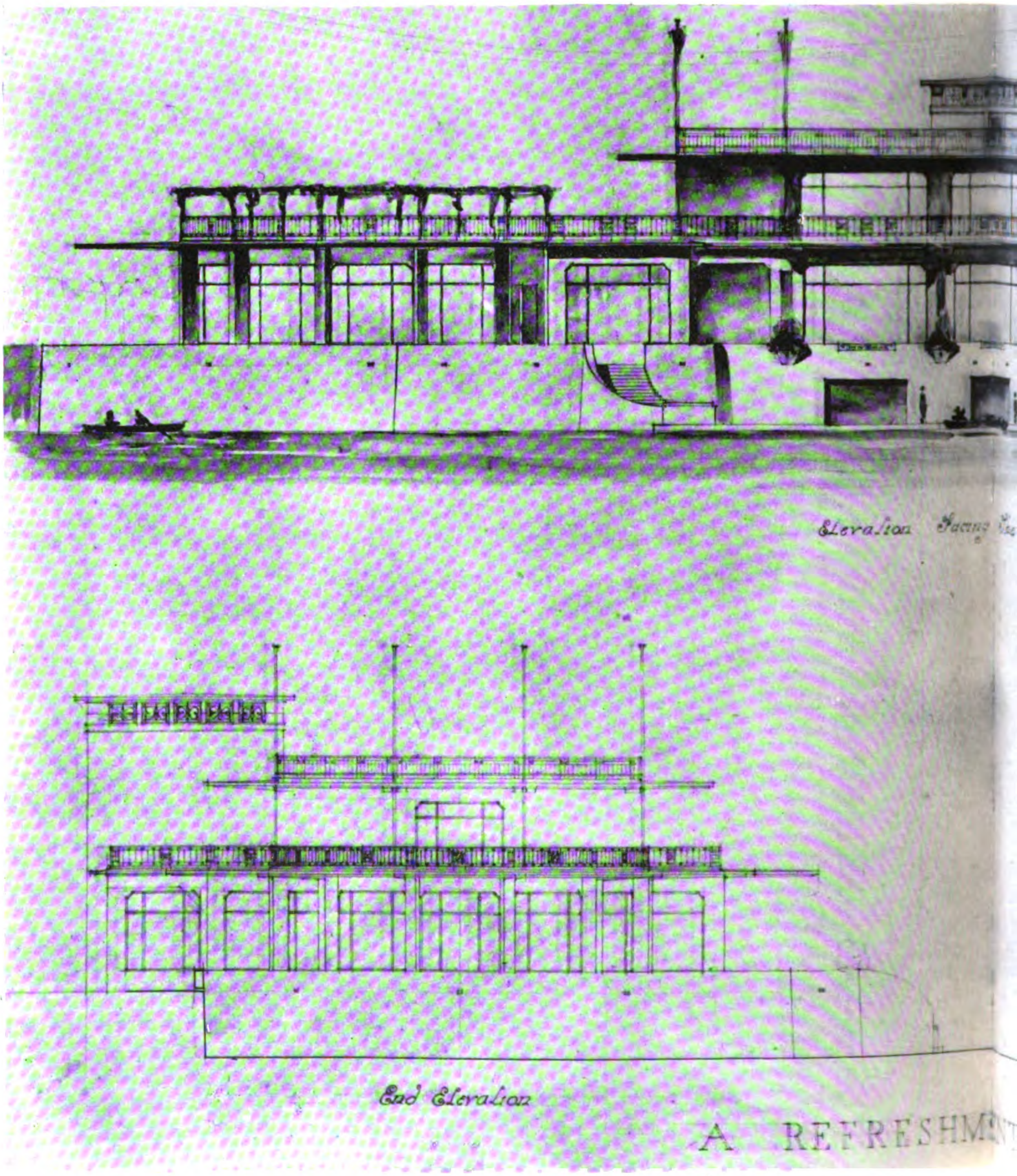
FIG. 6. HEAT EXPANSION IN WATER

"Concrete and Constructional Engineering" Prize Design.



DESIGN FOR A PAVILION ON THE SERPENTINE. Awarded "First Mention."
By Mr. F. Jenkins (London University School of Architecture). (*See p.* 570.)

"Concrete and Constructional E



DESIGN FOR A PAVILION ON THE SERPENTINE. Awarded " First Menti

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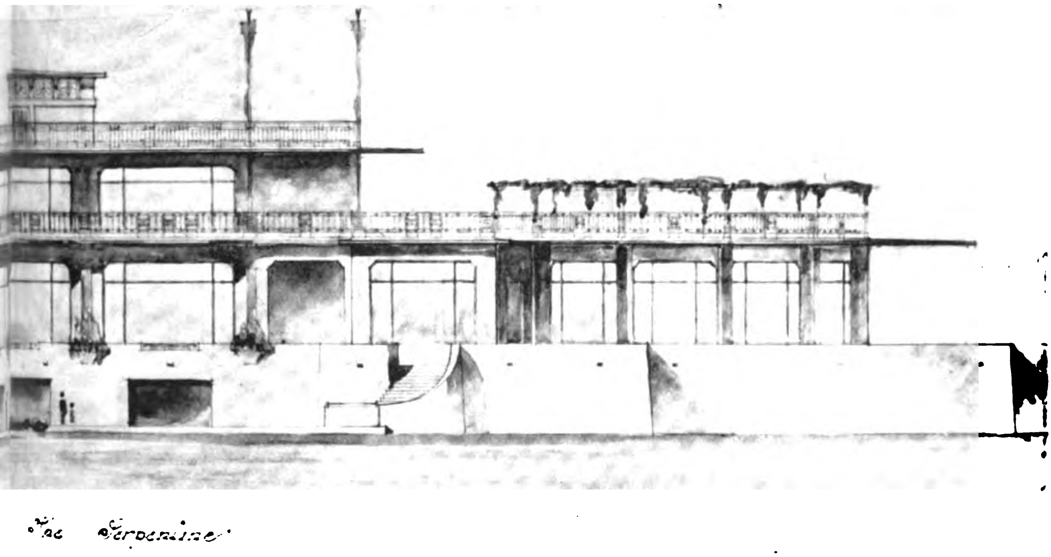
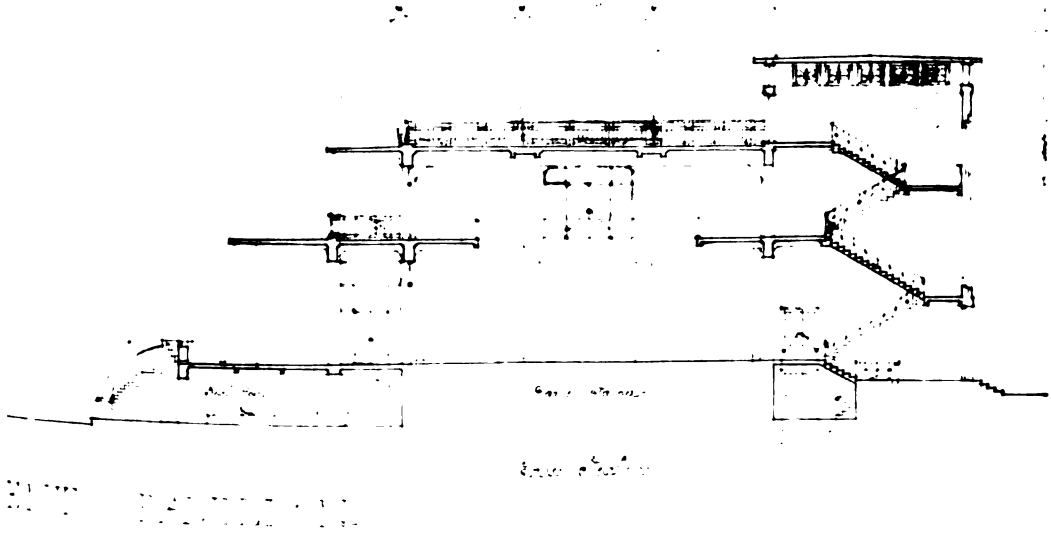
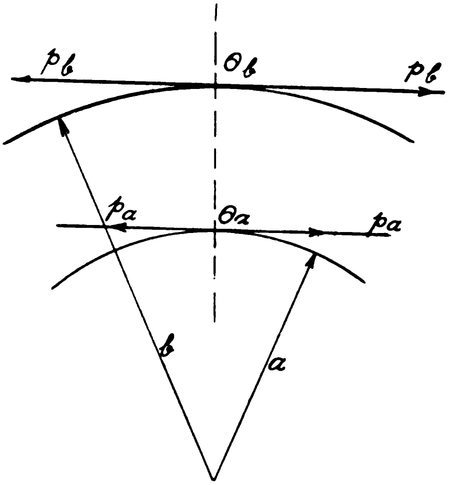




on." By Mr. F. Jenkins (London University School of Architecture). (*See p.* 541.)

(*Continued from p.* 568.)

These stress values result from the assumption that E is constant and equal to 2×10^6 lb./sq. in., actually the stress strain curve is not a straight line and the effect is to even out the stress to some extent. With certain concretes E may be considerably higher than 2×10^6 lb. per sq. in., and the induced stresses will be increased proportionately. However, the strength of concrete in tension is not likely to be more than about 200 lb. per sq. in. and may easily be as low as 100 lb. per sq. in., so that cracking is certain to occur even with smaller temperature differences than those present in the case under examination.



The stresses set up by a temperature difference of 10° C. are 130 lb. per sq. in. compression internally and 110 lb. per sq. in. in tension externally. If, therefore, moisture expansion in these experiments may be regarded as equivalent to a 10° C. temperature difference, cracking will not necessarily occur as a result of moisture expansions alone. No cracking was actually recorded from this cause, although it is possible that fine hair-cracks had commenced to form.

The stresses engendered by combined moisture and temperature will be the sum of the separate stresses, i.e. 660 lb./sq. in. compression internally and 550 lb./sq. in. tension externally.

It should be noted that cracking does not necessarily mean complete failure or even leakage, because immediately a crack is formed the effective area remaining uncracked is subjected to a smaller temperature or moisture difference.

In the case of tanks which are reinforced, although the reinforcement is effective in reducing the tensile stresses engendered by moisture expansion, as this expansion only affects the concrete it is useless as a complete safeguard against temperature cracks, since under normal practical conditions the steel expands uniformly with the concrete. Reinforcement at the centre of the wall of the tank is particularly ineffective because it is placed approximately on the neutral axis, where, in the case of temperature expansion, there is no stress for it to take up until the concrete has actually cracked. The only useful method of reinforcement would seem to be by a suitable mesh reinforcement placed near the outside in order to reduce the magnitude of any individual cracks to such dimensions as to be no serious detriment.

The tensile stresses can, of course, be reduced by applying, by external bands, an initial compression load, but in this case the compression stresses on the internal face will have to be carefully considered.

Permeability of Concrete.

As our readers will be aware, an exhaustive series of tests on the resistance to water of building materials is being undertaken at the Building Research Station at Watford under the direction of Mr. R. E. Stradling, D.Sc., Director of the Station. The investigations on the permeability of Portland cement concrete are being undertaken by Mr. W. H. Glanville, B.Sc., A.M.Inst.C.E., and an account of these investigations to date has been issued in a Bulletin of the Building Research Board.*

The investigation was undertaken with the object of determining the conditions influencing the permeability of concrete and their relative importance. The subject falls naturally into three sections and each of these is considered separately in the report. These sections deal respectively with :—

(1) The influence of the constituent materials.

(2) The effect of the methods of preparing concrete.

(3) The influence of the subsequent treatment of concrete.

In an Introduction it is stated : "It has been repeatedly demonstrated within recent years that it is possible, with mixes of normal proportions, to produce a concrete which shows no leakage even when subjected to considerable water pressure. It is generally admitted, however, that in actual structures great care and expert supervision are needed to prevent the formation of cracks, an evil which is responsible for a large proportion of the failures that occur. Cracks are often caused by structural defects and as such do not fall to be investigated under the strict definition of permeability. Structural defects of this kind are generally traceable to careless jointing between successive days' work, the inefficient placing of reinforcement, and inadequate allowance for shrinkage. No attempt has accordingly been made in this investigation to analyse these conditions, but it cannot be too often repeated that it is of little use devoting attention to the actual permeability if in design and during construction consideration of the causes of structural defects is neglected."

Permeability may be defined as that property which permits the passage of a liquid through a material and is thus distinct from the penetration of moisture into a substance by means of absorption due to capillary action. Until the liquid has penetrated through the material the rate of flow results from a combined pressure and capillary action, but when penetration is complete capillary attraction ceases and the rate of flow depends only on pressure. This rate of flow is a measure of the permeability of the material. Permeability must, therefore, be due to the existence of continuous passages right through the substance, and in order to examine the causes of permeability it is necessary to examine the nature and formation of these passages.

The first point, which is of fundamental importance in the study of this subject, is that, for any given concrete, permeability is a continually varying property, since it is intimately connected with the condition of the cement. The more complete the hydration has been, the less permeable the concrete becomes. For this reason in most cases the curing conditions and the period of subjection to water pressure outweigh other considerations and, for all normal mixes, are of greater moment than grading, water content and other factors, although each of these may influence permeability to a considerable extent.

In examining the causes of permeability, it is necessary, therefore, to presuppose passages through the concrete which can change with varying conditions in the cement ; that is, that they must be bounded either wholly or partly by cement particles. Since permeability decreases with increasing cement content, and neat cement itself is comparatively impermeable, the passages must be caused by conditions not present in the case of neat cement, for example, the presence of aggregate, or a greater ratio of mixing water to cement. The degree to which each is responsible will depend on the particular mix.

The passages, however they are formed, must be part of the voids which are always introduced in mixing. These voids may be considered in three stages:

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* "The Permeability of Portland Cement Concrete." Building Research Technical Paper No. 3. (London : H.M. Stationery Office. Price 1*s*. 6*d*. net.

First, in the dry materials when they are mixed together; in this case there are air voids only.

Second, in the mix as it lies in the moulds before setting takes place; here the voids are of two types, air voids and water voids.

Third, in the set concrete, when they may again be air or water voids but in different proportions.

The conditions in each of these three stages are different and the distribution of voids will not be the same. In the first condition, the absence of water, and therefore of surface tension effects, makes it unlikely that the distribution of voids will bear much resemblance to that in the final state. In the second, the influence of surface tension, together with ramming, is introduced. In the last condition, where the concrete is more or less dried out and the cement changed in volume, the size of the pores alters to an extent depending on the curing conditions.

Some experiments have been carried out on the voids in their second stage, in which the mortar voids (*i.e.*, those which occur in the concrete before setting) have been examined. It has been found, in general, that when the cement content is maintained constant the lower the proportion of the voids the more impermeable is the concrete. This is generally regarded as almost axiomatic but it is, however, by no means of universal application since the particular manner in which the voids are distributed varies and may play an important part.

However, it is the final distribution of voids in the set concrete which must directly influence its permeability. Some of these voids occur in the form of cavities more or less spherical in shape and of sizes varying over a large range; they can be seen with the naked eye when a piece of concrete is broken open and the fractured surface examined. It has been suggested by Moullin that voids are also present in the form of fine tubes, some of which form connecting ducts between these cavities. In a system of this kind it is possible for three conditions to exist. First, some of these cavities and channels may be entirely within the concrete and unconnected with either of the surfaces; second, they may connect with one face only; and, third, they may form continuous passages right through the material. The channels must necessarily be of fine diameter and where connected with a face would form a means of absorption of a liquid. Connection between opposite faces right through the mass would mean that provided the channels were of sufficient size, it would be possible to force a liquid through. It is to the existence of these continuous channels that permeability is due.

The distribution of voids in concrete has received further attention from Maier, who divides them into two main classes, macroscopic and microscopic. He has further classified the macroscopic pores, according to their method of formation, into three groups, water concentration pores, structure pores, and border pores. The water concentration pores are evidently the spherical cavities referred to above and are due to the excess water forming into globules by surface tension. The structure pores are caused by deficiencies in the mix, and the border pores by bad bonding between aggregate and cement. The microscopic pores appear to correspond to the connecting channels mentioned by Moullin.

If it be assumed that the channels are of such dimension and form that the laws which apply to capillary tubes hold good, it follows that the permeability is directly proportional to the number of continuous channels and to the fourth power of their diameter, and varies inversely as their length. It is dependent also upon their character as regards changes of cross section. An analysis from this point of view has been given by Toy. He assumes that the whole of the voids in the concrete go to form continuous channels through the mass. There is, however, no certainty as to how far this state of affairs exists, and it is, therefore, difficult to gather from the results of permeability tests only any satisfactory clue as to the exact character and dimensions of the channels. Calculations from such results for a typical specimen of concrete 2 in. thick show that if it be assumed that all the water passes through one tube of length equal to the thickness of the slab the diameter of this tube is about 0·01 cm. The height to which water will rise in a capillary tube of this diameter is about 15 cm. Actually the water must pass through, not a single capillary tube, but a large number, and their diameters must be considerably less than 0·01 cm., and it would therefore be expected that the water would rise in a specimen of concrete for a distance greater than 15 cm. Experiments on a rod of mortar (of composition equal to that of the mortar in the concrete) with one end immersed in water showed a rise of only 8 cm. Although the exact cause of this is not clear it may be that the channels are of such a character that the ordinary laws of capillarity do not hold. It has also been thought that it might be due to a lack of continuity in the passages, a possibility suggested by the fact that permeability decreases as the thickness of concrete increases, but in much larger inverse ratio. For the material to be permeable, however, some continuous passages must exist and therefore, if the ordinary laws hold, the water would be expected to rise the full distance; even when evaporation losses were practically eliminated by suitably coating the sides of the specimens no appreciable increase in height was obtained.

A summary of the results of the investigations is as follows:

Water Content—With uniform ramming the quantity of water which produces minimum volume of concrete also gives minimum permeability and maximum crushing strength.

The influence of water content is one which is very marked at early stages in the life of concrete, but decreases with age.

When ramming is maintained constant, the use of too little mixing water causes a greater increase in permeability than the use of too much.

The influence of water content is one which is greater with lean mixes, and decreases as the proportion of cement is increased. It is important to note, however, that, although the increase varies in quantity for mixes of different cement content, the increase bears approximately the same ratio to the minimum permeability in all cases. Thus, if the addition of 2 per cent. extra mixing water increases the permeability of a 1 : 1 : 2 mix to three times its initial value, a similar increase of 2 per cent. will also increase the permeability of a 1 : $3\frac{1}{3}$: $6\frac{2}{3}$ mix three times.

The laws connecting permeability and water content are represented approximately by:—

$$P = p\ 2{\cdot}4d$$

where p = permeability at normal water content (that required for minimum volume of concrete).

d = percentage increase in water content above the percentage at normal water content, both percentages being reckoned on the whole weight of dry materials.

(Thus if $W_1\%$ = percentage water to whole weight of dry materials in mix of normal water content and $W_2\%$ = same for increased water content, $W_2\% - W_1\% = d\%$.)

P = permeability with increased water content.

This relation holds at the age of 28 days and after 24 hours on test at 100 lb./in.^{2}.

Cement—Cement and water content are of approximately equal importance.

With well-cured concrete mixed with the best quantity of mixing water an increase of cement content above that in a 1 : 2 : 4 mix does not materially affect permeability. Very wet mixes require a richer mix, about 1 : 1·3 : 6·2. Inefficient curing conditions also mean that a greater cement content is required for equal impermeability.

The rate of decrease in permeability is dependent upon the cement content. With two mixes of equal maximum permeability, that containing the greater cement content will decrease in permeability at the greater rate.

Aggregates—The careful proportioning of the aggregates is of much less importance than the use of the correct quantities of water and cement.

The sand content plays a more important part in determining the permeability of a mix than the gravel content (with porous aggregate such as broken brick this would not necessarily hold).

Grading to Fuller's Best Mix Curve considerably reduces the permeability of lean mixes, but it is of much greater importance to see that sufficient fine material is present.

The sand which with a 1 : 2 : 4 mix produces the most impermeable concrete is that which passes through a 30-mesh sieve and is retained on a 40-mesh sieve, *i.e.*, approximately $\frac{1}{50}$-in. in diameter.

The fineness of the cement possibly has some influence on this result.

Additions—There are many finely powdered inert additions which decrease the permeability of concrete of lean proportions. To call the inert powdered material a "filler" is not always correct, since sometimes, although the permeability decreases, the voids may increase. In a 1 : 2 : 4 mix finely powdered sand used to replace up to 50 per cent. of the cement has about half the value of an equal quantity of cement, as far as permeability is concerned, but has no value as regards crushing strength.

The following are examples of powdered materials which have been found effective: Powdered sand, hydrated lime, powdered slate waste and red mud.

Mixing—It has been shown by Withey that longer periods of mixing are required by lean mixes than by rich.

Ramming—Prolonged ramming does not appreciably affect mixes of normal consistency; with drier mixes it reduces the permeability and the mortar voids, and increases the crushing strength.

For prolonged ramming, as with normal ramming, the points of minimum permeability, minimum voids and maximum crushing strength occur for one percentage of mixing water.

The decrease in permeability obtained by prolonged ramming is not considerable and probably not sufficient to warrant the extra labour involved.

Trowelling—Trowelling the surface of concrete reduces the permeability of dry mixes but has little effect on wet mixes.

Method of Casting—Both for wet and dry mixes, specimens cast on edge are more permeable than those cast flat.

Surface Treatment—Wire-brushing the surface of a specimen of 1 : 2 : 4 concrete on edge approximately doubles the permeability.

Age—With water-cured 1 : 2 : 4 concrete the permeability is high at short periods from mixing, but gradually decreases until, after the age of one month, the changes which occur are comparatively small.

The permeability of air-cured concrete does not decrease appreciably after the age of fourteen days.

Curing—Curing conditions play an important and fundamental part in determining the permeability of Portland cement concrete; their influence is greater than that of any of the other factors considered. With high aluminous cement concrete their influence is not nearly so pronounced.

The best concrete is obtained by storing in water, and the nearer conditions approach this the more impermeable the product.

The days immediately following mixing are the most important. At later periods very long periods of water-curing are required to give a badly cured concrete impermeability equal to one which received better early treatment.

Impermeability produced by good curing is permanent in character for 1 : 2 : 4 mixes.

Although, through different curing conditions, concretes may be of widely different initial permeability, this difference decreases under continued subjection to water pressure. For this reason it appears that high permeability due to inefficient curing is probably not of such lasting detriment as high permeability due to other causes.

Test Pressure—Initial permeability is proportional to pressure, but this relationship is not maintained. After 7 days on test, specimens tested at 25, 50 and 100 lb./in.^{2} were of equal permeability. The higher the pressure the greater is the rate of decrease in permeability.

Reduction of Permeability of Specimens during Testing—This reduction is due to a combination of three causes: internal silting, hydration, and swelling. The amount attributable to each depends on the conditions of the test and the composition of the concrete.

High permeability is accompanied by a high rate of decrease. In this way, the higher the test pressure the greater the rate of decrease.

Of concretes with the same initial permeability that containing the higher percentage of cement will decrease in permeability the more rapidly.

The silting-up action is of a permanent nature, the particles being cemented into position.

With high rates of flow and with high pressures, swelling plays a relatively unimportant part in the process of slowing-up, but increases in importance at lower rates of flow. With pure absorption, as shown by water rising vertically by capillary action, only, swelling is the main cause.

The rapid bulk-swelling which occurs during the first two days after a concrete is immersed in water has comparatively little effect on permeability.

Considerable hydration takes place when concrete is subjected to water pressure.

High-Aluminous Cements—Although high-aluminous cements have other valuable properties they are most often used in the production of concrete where early strength is desired. It is necessary, therefore, to examine the effect of age on permeability and compare it with the effect of age on the permeability of Portland cement concrete.

The tests show that at the age of one month there is no great difference between the permeability of Portland cement concrete and high-aluminous cement concrete provided they are both cured in water, conditions which, of course, can rarely be attained in practice. When stored in air, however, results are very divergent: the Portland cement concrete remains highly permeable with practically no change with age, while the high-aluminous concrete, which at two days old is one-fifth as permeable as air-stored Portland concrete at one month, becomes less permeable with age so that at one month the air-stored high-aluminous concrete is as impermeable as water-stored Portland concrete. Owing to the difficulty of obtaining the best curing conditions in practice these results are important and show that the high-aluminous concrete must be regarded as a much more impermeable product. It must be remembered, however, that this does not cover the possibility of danger from shrinkage cracks, which is always greater with air-stored concrete.

It is interesting to note that the same phenomena are observed in testing high-aluminous concrete as with Portland concrete. The reduction in permeability with time on test is very much of the same order. The water coming through contains a considerable amount of lime in solution as with Portland cement concrete; the samples analysed were all saturated.

Rapid-Hardening Portland Cement—The remarks made with respect to the effect of curing conditions on high-aluminous cements apply equally well to rapid-hardening Portland cement.

Fees for Designing Reinforced Concrete.

A SERIES of interviews has taken place between the Association of Consulting Engineers and the Chief Engineer of the Ministry of Health on the question of fees for designing reinforced concrete structures for which the sanction of the Ministry is necessary. These discussions are summarised as follows by the Association in its report for the year ended April 30, 1926, and recently issued :—

(1) The object of the Ministry is to ensure that all fees for design and superintendence shall be kept entirely distinct from constructional costs, and be paid direct by the authority and not through a contractor, either as fees or hidden in the price of steel or other materials, and that the scheme as submitted to the Ministry should be put out to open tender.

(2) Where a consulting engineer is called in to advise on a scheme submitted by a reinforced concrete firm or others, any sum or fees the authority may have paid or agreed to pay to such firm and/or to the consulting engineer for design or superintendence which will be sanctioned by the Ministry to be paid out of the loan, shall not exceed the fees which a consulting engineer would have been entitled to charge if he had designed and superintended the work by himself.

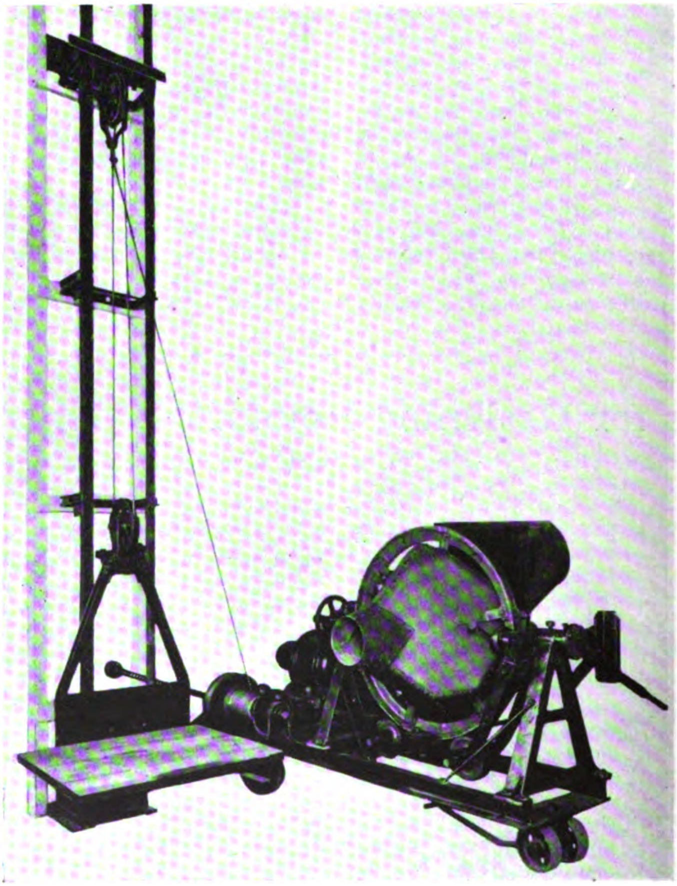
(3) If the consulting engineer employs a reinforced-concrete firm or specialist to prepare a design for him, such firm or specialist should be paid by the consulting engineer, as under these conditions they are in effect part of the consulting engineer's staff.

The Committee of the Association is of opinion that the minimum rate of commission for such work should be 7½ per cent. on the cost of works amounting to £10,000 or over, and on smaller works a graduated increasing rate as the cost of the works decreases, until on very small and intricate works it be at least 12 per cent.

New Mixing and Hoisting Plant.

We illustrate a combined concrete mixer and hoist which, although only recently put on the market, has been used in the construction of some large building works in London. The outfit is compactly arranged so that the mixer discharges direct into a skip or wheelbarrow on the platform of the hoist, thus avoiding double handling. Mixer and hoist are driven by the same electric motor or petrol engine.

The mixer drum is of a new type, known as a " cube " mixer, in which the material is thrown from one face to another and also backwards and forwards, six times to each revolution of the drum, thus giving a rapid and thorough mix. The mixers, which are also supplied separately, are made in sizes from 3 to 21 cu. ft. batch capacity, and for hand or power operation. The manufacturers are the A.C.E. Machinery Co., Ltd., of Pordon Road, Brixton, S.W.

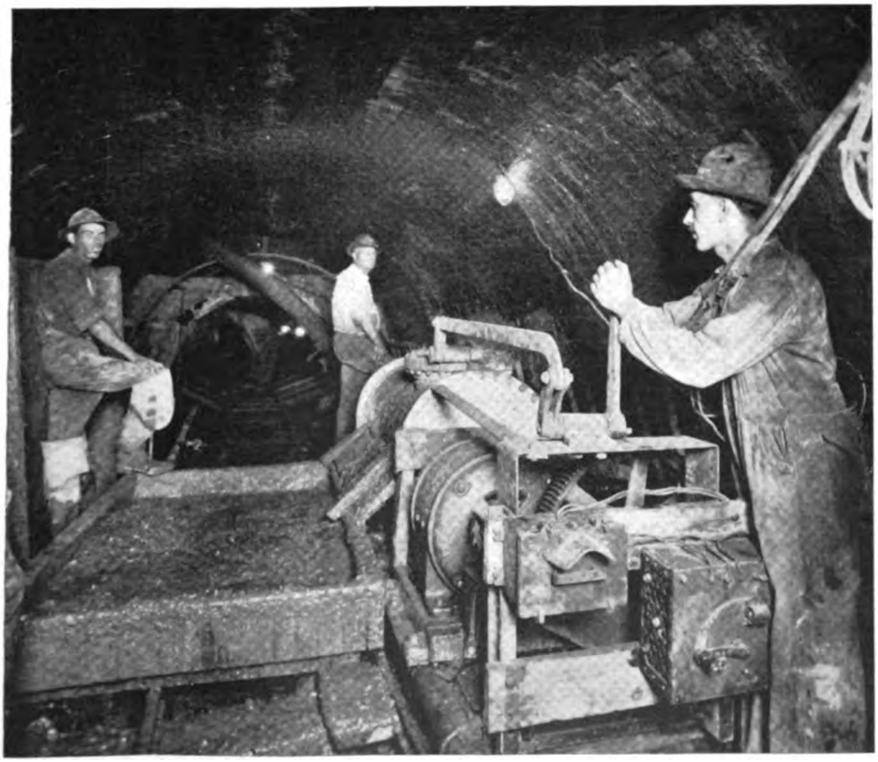


Concreting a Brick Sewer with Compressed Air.

AIR compressed to 85 lbs. in a portable machine of 300 cu. ft. free-air per minute capacity serves a double purpose in the work now being done for the Bureau of Sewers, Brooklyn, New York.

About 2,500 ft. of old brick sewer, 10 ft. in diameter, is now being reinforced by lining the arch and side walls with reinforced concrete, the concrete being mixed in a machine installed in the street over the sewer tunnel, dropped through an 8-in. vertical pipe to ½ yd. trucks that take it to a horizontal pneumatic placing machine that shoots it into the forms at a rate of about 7 cu. ft. (one batch) in 15 seconds.

A 1½-in. compressed-air pipe is carried down the construction shaft in the street and run through the sewer in opposite directions to the two headings, in each of which it operates pneumatic chipping hammers with which a portion of the brickwork is cut out on each side of the sewer to make a side wall recess with the triangular cross section reaching from the apex (9 or 10 in. above the tunnel axis) to a point about 3 ft. below the axis, where it has a horizontal base (18 in. wide) for the new side wall (3 ft. high and 14 in. thick) at the top where it joins the semicircular concrete arch ring (12 in. thick) at the crown, which is reinforced near the intrados with transverse and longitudinal bars and forms a heavy lining to support the somewhat precarious old brick arch and has ample strength to resist all stresses independently of the old cracked brickwork. Six men, who also assisted the timbering and other work, remove about 11 yds. of brickwork in 8 hours,



The Concrete Blower at Work.

and load it into ½-yd. trucks by which it is removed to the foot of the shaft and hoisted by a stiff leg derrick equipped with an engine.

The side walls are built in 14-ft. sections kept several days in advance of the arch concreting. Rigid wooden arch centres covered with wooden lagging and closed at the forward end by bulkhead boards are adjusted by wedges, and concrete, about 1 yd. per linear foot, is placed on them by a new type horizontal machine of small dimensions that is installed in the tunnel, about 20 ft. from the bulkhead, on the floor platform above the invert, alongside and clear of the 24-in. track. This machine has an air-tight barrel 4 ft. long and 2 ft. in diameter, with a 12-in. electrically-driven helicoidal conveyor, parallel to its axis, installed in the lower part. Concrete in 7 cu. ft. batches is shovelled into the barrel through a hole closed by a conical gasketed door operated by air pressure. Air at 85 lbs. pressure is admitted to the barrel, and escaping through the outlet at the lower part in the forward end produces a suction that pulls the concrete through the 6-in. discharge hose that extends through the top of the bulkhead. The operation of the helicoidal conveyor assists the last of the batch to the outlet, and the 15–18 yds. of concrete required for the 14-ft. section of arch that each gang completes daily is placed in 3 hours with an average of about 66 shots, although the rated capacity of the machine is 15 yds. per hour for distances up to 45 ft.

The nozzle of the discharge hose is kept a short distance clear of the concrete already in position, and the wet concrete is impacted against it and falls down on both sides of the arch centre, filling the form up to the crown as the hose is gradually withdrawn and, by the force of the air pressure, packing the most difficult portion, the crown key, more rapidly and effectively than by hand, ensuring dense, strong concrete and a smooth soffit when the form is removed by slacking the wedges and advancing it on rollers.

This method of placing the concrete is considered very convenient and satisfactory, especially because it gives minimum obstruction in the very small tunnel. It leaves plenty of working space and track clearance, and saves about 30 per cent. of labour and 50 per cent. of time over the same work done by hand.

It is estimated that the application of the suction instead of the pushing action in the discharge hose, and the other advantages of this machine, effect a saving of 60 per cent. or more of the compressed air that would be required for the same service by the gravity type pneumatic mixer that required for its operation at least 750 cu. ft. of air per minute.

The forcible impact of the concrete delivered from the nozzle of the discharge pipe tends to produce extra dense strong concrete and eliminates the difficult hand placing and ramming in the key concrete at the crown of the arch. The simplicity of the operation, direct action, portable apparatus, long radius, and extreme flexibility of the discharge hose especially adapt this method of placing concrete to difficult and inaccessible places and to operations in a very limited clearance as in tunnels, conduits, shafts, for repair work, and where there is little room except for the man operating the nozzle. The machine handles considerable quantities of concrete in a manner comparable with the placing of grout and cement mortar with the cement gun.

This machine is the first of its type ever built, and after using it for a month in the Greene Avenue sewer we are informed the contractor removed it for more important work in placing the concrete lining for the great vehicular tunnel under the Hudson River, New York, where the forcible delivery of the concrete may be advantageous in penetrating narrow openings and consideration is being given to the use of a 4-in. instead of a 6-in. discharge hose.

The engineer for the work is Mr. A. J. Griffin, and the contractors Messrs. Booth & Flinn.

Design of Skew Arches.

It has frequently been assumed that the stress distribution in concrete skew arches was similar to that in a symmetrical right arch. The United States Bureau of Public Roads has now carried out a series of tests which show that this theory is erroneous; it was hoped that a more rational basis would be discovered for bridge designing, but while this hope has not yet been fully realised the results have been encouraging and research will be continued.

The tests were made on model concrete arches, one-quarter size, with skews of 15, 30, 45 and 60 degrees. The span parallel to the faces has been in all cases 7 ft. The results so far attained have led to the following general conclusions, which are considered by American engineers to lay down the lines for future approach to this problem:

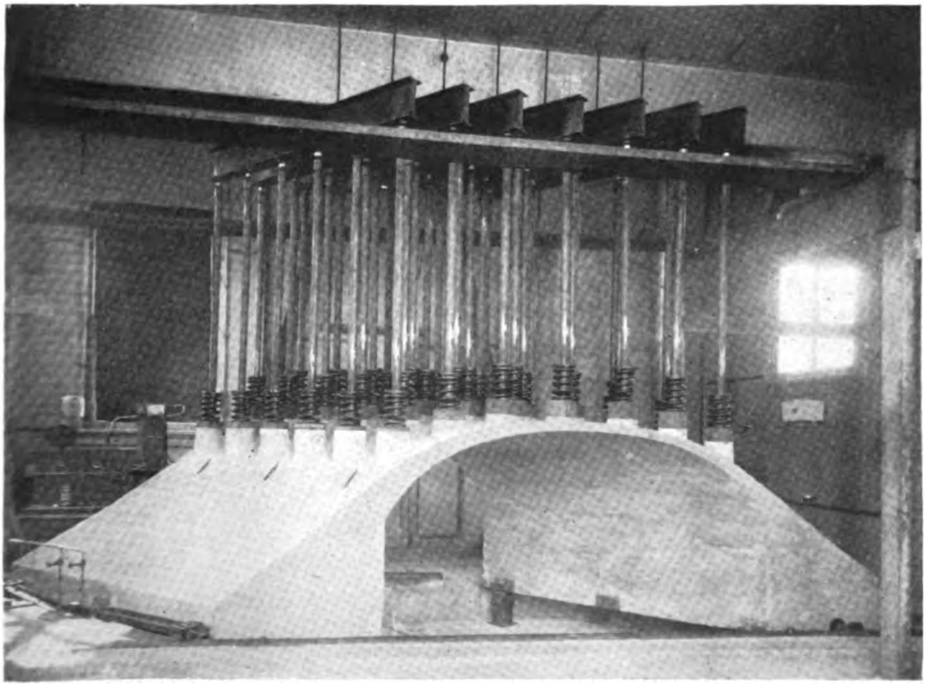
(1) The vertical reactions varied uniformly from a maximum at the obtuse angle of the arch to a minimum at the acute angle.

(2) The increase of the vertical reaction at the obtuse angle varies directly as the angle of skew.

(3) The resultant pressures of both the horizontal and vertical components move toward the obtuse angle of the arch with an increase in the skew.

(4) The direction of the side thrust is towards the face of the arch, at the acute angle, and the intensity increases with the degree of skew.

Uniform loads were applied on 42 symmetrically-placed loading points on the arch ring by compressing helical springs 5 in. in diameter, and 7 in. high, of a uniform compressive strength of 915 lbs. per in. Forty-two vertical struts of 1½-in. pipe bolted at their upper ends to a cribbing of I-beams took the vertical thrust. This cribbing was supported by a heavy beam directly over the experimental arch, and the carrying beam was in turn supported at each end by a 2-in. bolt which engaged a steel yoke bolted to the webs of two upright channel irons



Method of Applying Test Loads on Reinforced Concrete Skew Arch.

anchored to the floor and separated from each other by a space sufficient to clear the overhead beam. By this method the entire cribbing could be raised or lowered by nuts running on the supporting 2-in. bolts.

The compression of each spring is measured by a fixed scale, and a moving vernier is actuated by a plunger inside the strut. As the plunger rests at the centre of the springs, the compression measured is the mean compressive power of the spring. Scales and verniers read to the hundredth part of an inch or the nearest 10 lbs. of load.

The 60-degree arch was poured in April, 1923, and loaded to destruction on December 11. The total load applied was increased by instalments of 4,200 lbs., equal to 100 lbs. on each of the 42 springs. The arch failed under a total load of 25·2 tons, equivalent to a spring load of 1,200 lbs. Six test cylinders made at the time the arch was poured showed at the end of 125 days a mean breaking strength of 4,235 lbs. per sq. in. and an average modulus of elasticity of 3,370,000.

The 30-degree arch was poured on December 15, 1923. The loading was the same as for the first arch tested, but a further improvement was made in that the rotation of the strain gauges was prevented by placing wooden wedges between the body of the gauge and the arch. This gave strain-gauge readings consistent for equal loads. The maximum compression developed under a total load of 16,800 lbs. was 630 lbs. per sq. in. Six test cylinders showed a breaking strength of 5,240 lbs. per sq. in., and a mean modulus of elasticity of 3,813,000 at the end of 123 days.

The 45-degree skew was poured in April, 1924, and the same methods were employed. Test cylinders after 90 days showed a mean breaking strength of 4,885 lbs. per sq. in. and a modulus of elasticity of 3,309,000.

The 15-degree arch was poured in September, 1924, in the same way. After 80 days the test cylinders recorded a mean breaking strength of 5,060 lbs. per sq. in. and a modulus of elasticity of 3,151,400. Maxima were found at the obtuse angles, and showed a maximum tension of 138 lbs. per sq. in. and a maximum compression of 378 lbs. per sq. in. under a total load of 16,800 lbs. on the entire arch.

The engineers in charge are of opinion that no direct comparison of stresses as measured in the arches of various degrees would have any value, owing to the differences in temperature existing during the periods in which the tests were made.

Caversham Bridge.

In connection with the construction of Caversham Bridge, described in our last issue, for the purpose of architectural treatment the engineers, Messrs. L. G. Mouchel & Partners, Ltd., obtained the collaboration of Messrs. Henry Tanner, architects, of 3 Hanover Square, W.1. The resident engineer was Mr. J. B. Wilson. On June 25, when the Prince of Wales unveiled the commemoration tablets, Mr. C. R. J. Wood, A.M.Inst.C.E., representing the engineers, and Mr. A. S. Parsons, M.Inst.C.E., the Borough Engineer, had the honour of being presented to his Royal Highness.

New Concrete Football Stand.

The Sunderland Association Football Club has decided to spend £30,000 in improvements to their ground at Roker Park, including a new concrete stand which will give accommodation for 10,000 additional spectators.

Reinforced Concrete Reservoir at Penrith.

IN order to increase the delivery of the 8-in. aqueduct from Hayeswater to Penrith, it was necessary to lower the aqueduct by means of a tunnel at Hause Crag and also to lower the position of the principal service reservoir at Penrith. The latter necessitated the construction of a new service reservoir on Fair Hill, 95 ft. lower than the principal service reservoir previously existing. It was also considered essential that more storage accommodation should be provided at the Penrith end of the aqueduct. The town had only one-and-a-quarter days' supply in store to meet a maximum daily consumption of 350,000 gallons. Such a condition was far short of safe in case of possible breakdowns along the seventeen miles between the source at Hayeswater (storage, sixty million gallons) and the town, and even neglecting breakdowns it had on several occasions of hot summer weather and severe frosts been extremely difficult to maintain the reservoirs at anything like full capacity.

The new reservoir holds 1,000,000 gallons, and allowing for a population up to 10,000, places the town in the position of having at least three days' reserve. The site of the reservoir was fixed with the view of establishing another zone for distribution in order that the high service reservoir zone could be contracted, thereby reducing the quantity to be delivered at the highest point of the distributing system. By fixing the site on Fair Hill the level would enable the town to receive an additional 100,000 gallons a day at that point. Filters were fixed 900 yds. from the head-works at Hayeswater to prevent the formation of nodular incrustations and to remove vegetable deposits which had formerly caused considerable trouble throughout the system, and especially in the distributing reservoirs.

The accompanying photographs and drawings (p. 586) give details of the reservoir. It was decided to erect a covered reservoir in this instance, the advantages of aeration of the water and action of the sunlight being outweighed by risk of pollution. Twelve ventilators were provided in the roof. The reservoir is approximately 124 ft. by 100 ft., with a partition wall down the middle, the depth of water being 13 ft.

The reinforced concrete roof is supported by 36 columns, 11 in. square and reinforced with four ¾ in. diameter bars encircled by machine-made hoops and helicals.

Fair Hill Reservoir, Penrith.

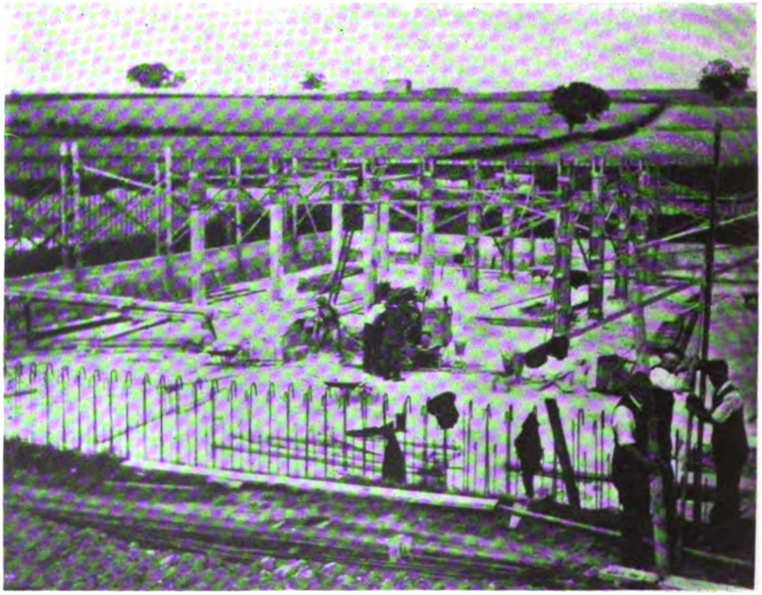
The walls are designed to span vertically between the roof and the floor, being taken as fixed at the bottom and freely supported at the top. The fixity at the bottom was ensured by increasing the thickness of the concrete under the walls, as shown on the drawing, and providing the necessary steel in this base. The thickness of the wall varies from 8 in. at the top to 12 in. at the bottom, and it will be realised from this what a great saving is effected in the concrete required as compared with mass construction. The arrangement of the mild steel bars in the wall is shown in the photographs. The main bars are vertical, and horizontal bars ½ in. diameter at 24 in. centres are also provided on both faces of all walls to provide for temperature and distribution stresses. The external walls are designed for the pressure from either the head of water in the reservoir or the earth backing acting independently, as it was considered that the backing might at some time dry away from the back of the wall, causing a space to be formed between. The inner partition wall is designed to withstand water-pressure from either side.

For the floor of the reservoir 1 in. of concrete was first placed and the reinforcement laid thereon in continuous lengths of fabric 7 ft. wide. The function of this reinforcement is to give tensile strength to the concrete to enable it to span over any uneven settlements which may occur in the ground beneath. As will be seen from the drawing, the base is thickened out under each column and reinforced with fabric in two directions (at right angles) to spread the load evenly on the ground.

The direct tension in the base slab is also taken by fabric, with the main wires at right angles to the length of the walls. This fabric is taken 12 ft. inwards. Beyond this point no steel is required for this purpose, as the frictional resistance of the tank bottom becomes sufficient to take the direct tension without overstressing the plain concrete.

The aggregate consisted of ¾ in. granite chippings from the Shap Granite Company, and river sand from Workington was used, as no suitable sand could be obtained in the vicinity. All the concrete used on the work was machine mixed, the proportions being 4 : 2 : 1 for the floor and roof and 3 : 1½ : 1 for the walls and columns.

On excavating to the specified level, half the bottom was found to be com-



Fair Hill Reservoir, Penrith.

Fair Hill Reservoir, Penrith.

posed of sandstone rock and half of sandy clay. Land drains were formed round the foundation to the walls leading to the sandstone, and by this means the water was drained away through the fissures in the rock. Under two-thirds of the columns, after excavation had been carried to the required level; the ground was found to be in such a spongy state, due to inclement weather, that about 6 in. of mass concrete was laid.

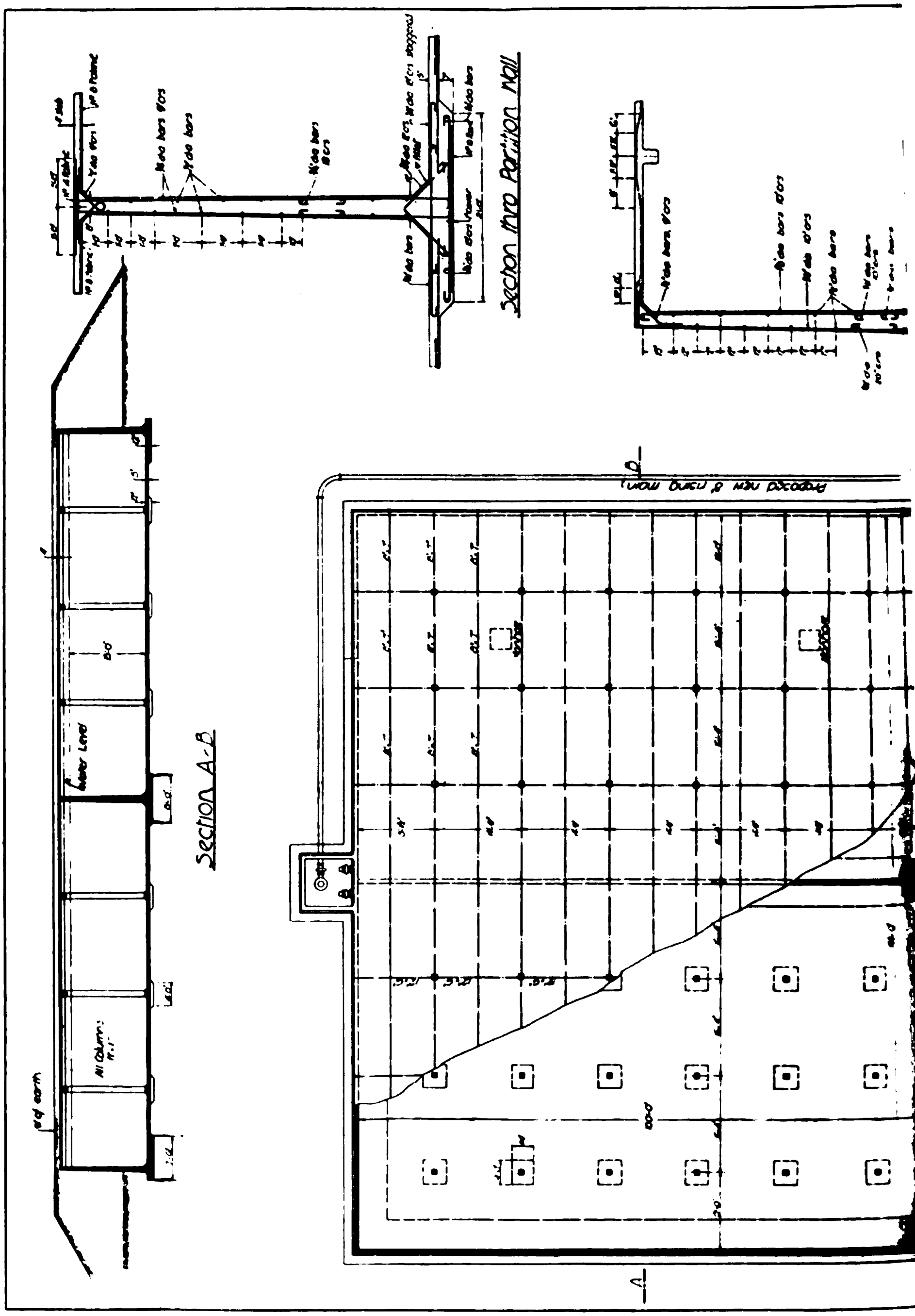
The mild steel bars were supplied on the work bent to the required shapes. The column fitments and stirrups for the beams were machine-made and ready for fixing on the bars. By this means the actual labour of fixing the reinforcements was reduced to a minimum.

The formwork for the walls was removed in from two to three days, depending on the weather. Sides of beams were removed in three to four weeks, and props to soffits in five weeks.

After completion of the work alternate compartments were filled for the purpose of testing, but no signs were shown of any leakage. The reservoir is now in use, and has proved completely satisfactory in every way.

No waterproofing composition was used on the inside of the reservoir, but a coating of cement was applied.

The work was carried out under the direction of Mr. T. H. Longstaff, A.M.Inst.C.E., water engineer and surveyor to the Penrith Urban District Council. The contractors for the work were the Cumberland Reinforced Concrete Construction & Artificial Stone Co., of Harrington, to whom every credit is due for the speedy and satisfactory carrying out of the work. The reinforced concrete portion of the work was designed, and the reinforcements were supplied, by the British Reinforced Concrete Engineering Company, Ltd., of Stafford.



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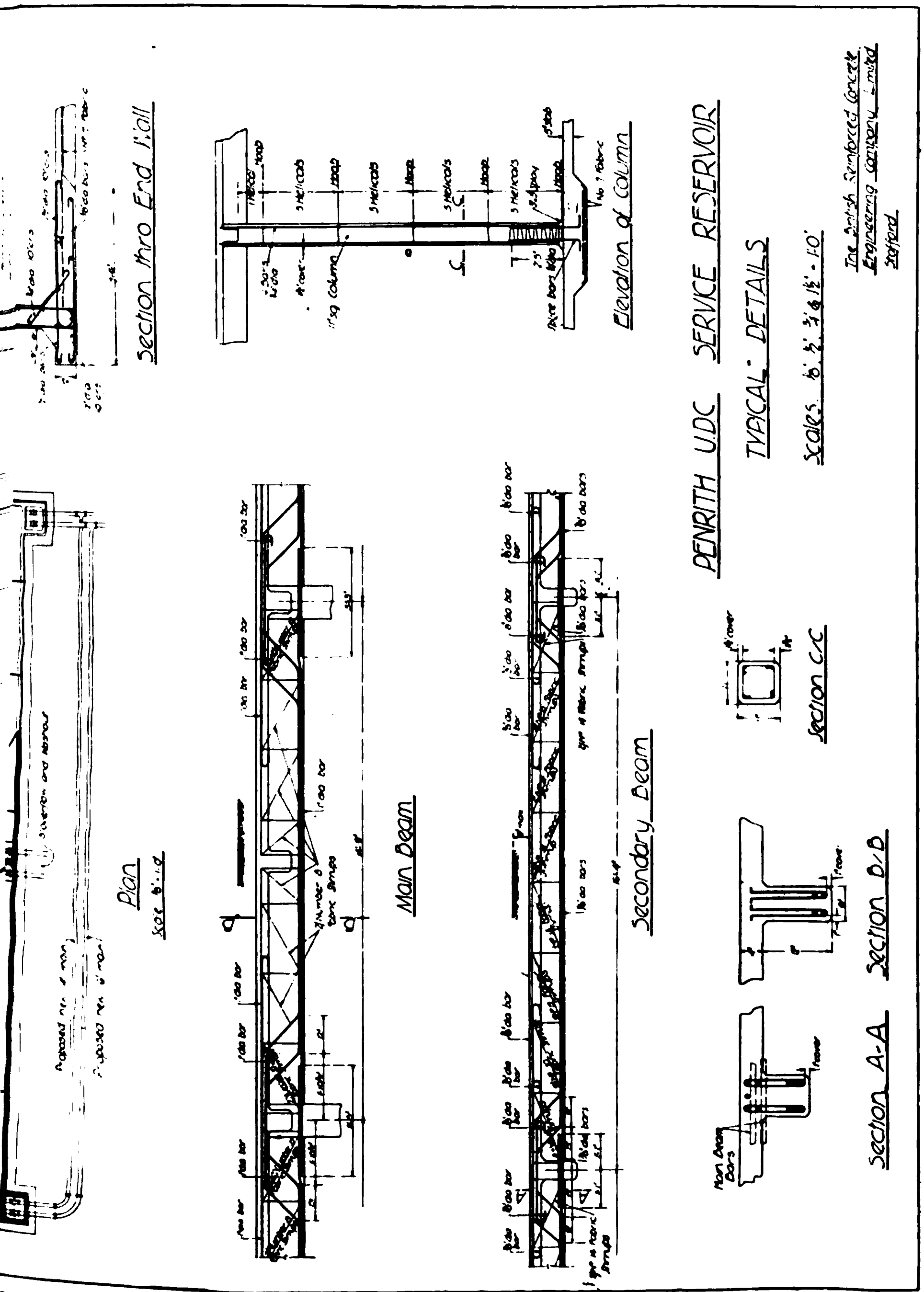

. Longstaff, A.M.Inst.C.E., Water Engineer and Surveyor to the Penrith Urban District Council.

VOIR AT PENRITH. (*See p.* 583.)

Controlling the Manufacture of Concrete to obtain Uniformity of Strength.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

[*Concluded.*]

Measuring the Material.

HAVING determined the economical proportions that will give a uniform strength of the desired value, the next consideration is the method of measuring the materials and water on the job. Jobs are of all sizes from 100 to 100,000 cubic yards, so that the methods and the plant used must necessarily vary to suit the job.

The smaller jobs will not stand the cost of much plant, but it is still possible to obtain uniform concrete, though not necessarily the most economical, by accurately measuring the cement and water. The amount of water and cement per batch is fixed by the water-cement ratio required and the size of the mixer. The cement is easily measured by the bag or cubic foot. The water can be controlled by a water-measuring tank—which should be part of the equipment of all mixers—by a pail, by a barrel with a gauge or float, or by rigging up a syphon which will deliver only a fixed quantity of water.

The water is controlled in the usual type of mixer water-measuring tank (*Fig.* 8) by a handle which raises or lowers the level of a syphon discharge pipe

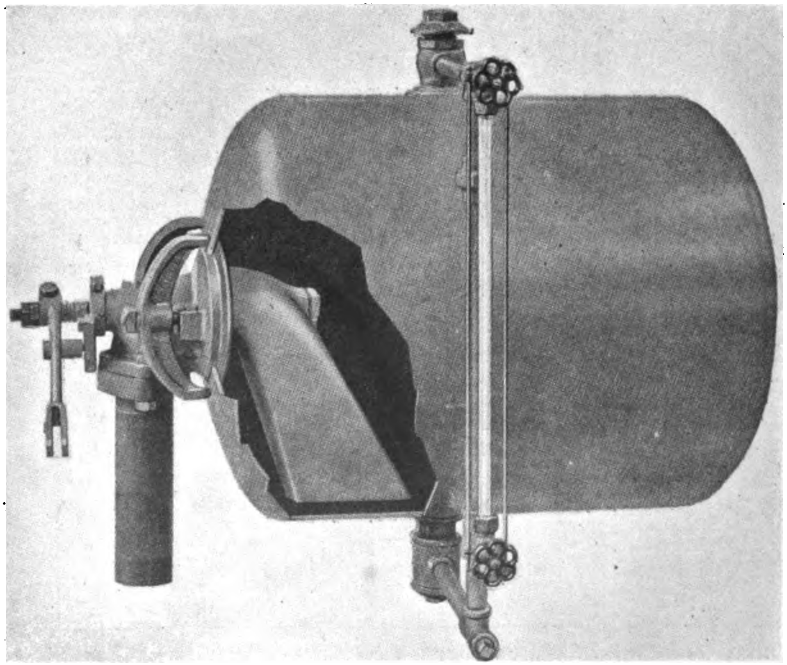

Fig. 8.—Water-Measuring Tank attached to Mixer.

inside the tank, the handle being set to the amount of water required. Taking water direct from the main line without any means of controlling its measurement should not be allowed.

If no tests of the aggregate are made, a few trial batches will determine approximately the best proportions between fine and coarse aggregate and the total amount that can be added to a fixed quantity of water and cement to give a required consistency. The consistency can be controlled by frequent slump tests. Any changes in the proportions will immediately show up in the workability and slump and can be corrected.

If the aggregates are measured in wheel-barrows the level should be struck off each time.

For the medium size and large job, say, from 500 cu. yds. up, we need a more accurate system of control for uniformity and economy. Measurement of the cement and water is the same as on the smaller jobs, water measuring-tanks always being used. The aggregates are measured by what are called " batchers."

Measurement of Aggregates by " Batchers."

The universal practice is to use overhead charging bins for feeding the mixer with aggregate by gravity. The bin is merely a rectangular wooden-framed box with a partition to divide the fine material from the coarse, and standing on a platform so located that the bin can discharge into the hopper of the mixer by means of two openings in the platform. The bin can hold 15 to 100 cu. yds., depending on the size of the job.

The flow of fine and coarse aggregate from the bin is controlled by batch boxes or " batchers." Two are required, one for fine and the other for coarse aggregate,

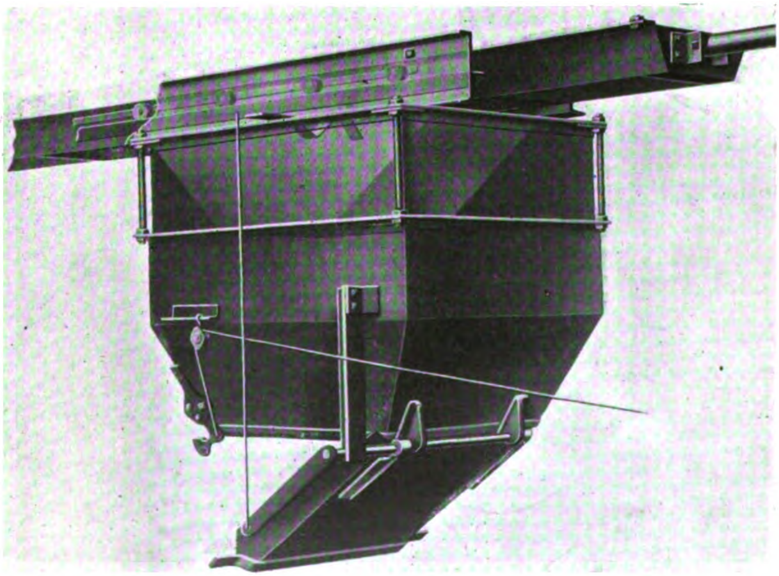

Fig. 9.—Adjustable Sand or Stone Measuring Batcher.

their size depending on the size of the mixer, and the stone batcher holding about twice as much as the sand batcher. These batchers are bolted on to the underside of the platform or bin, one at each opening. They are of all-steel construction, and are alike except for size.

Fig. 9 shows a view of a batcher. It consists essentially of a lower square box with sloping sides and a discharge gate, sliding into an upper collar which is attached to two channels by which the batcher is bolted to the bin. Over the collar and between the channels is an automatic strike-off gate running on rollers and operated by a lever. The lower box can be adjusted up and down within the collar by four bolts in order to set the batcher for any required volume. The gate closes automatically with a counterweight when the box is empty. The proportions of fine and coarse aggregate having being determined by the methods previously mentioned, the batchers are set to hold the required volumes and are not changed until the nature of the aggregate makes it necessary.

While the strike-off gate is closed the batcher is full of material. Pushing over the lever strikes off the material level with the top of the box and shuts off the flow from the bin. An indicator shows whether the box is full or empty.

Both batchers can be arranged to operate with the same lever. On pulling the cords fastened to the trips on the gates the aggregates are immediately discharged into the hopper. The lower box can be adjusted to discharge in any direction. Adjustment of the volume of sand due to bulking is quickly made by the four bolts.

The batchers then positively control the amounts of fine and coarse aggregates going into each batch. The proportions are designed to give a certain slump, and

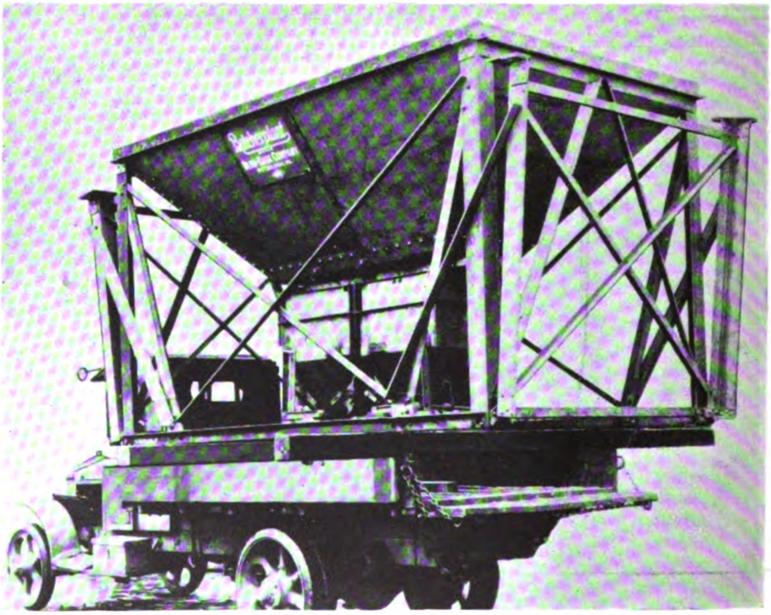

Fig. 10.—18-ton Batcher Plant Collapsed for moving by Truck.

this is checked daily or as often as necessary. Any change required in the proportions will show up in the slump.

Batcher Plants.

The combination of bin and batchers is called a " batcher plant," or " proportioning plant." Although the bins and platform may be made on the job with timber, most firms now use the all-steel batcher plants, which are made in any capacity desired, from the 18-ton plant that can be moved in one piece on a truck from job to job, to the 300-ton size for large permanent installations.

Fig. 10 shows an all-steel batcher plant of 18 tons capacity, collapsed for moving by truck, and *Fig.* 11 a batcher plant ready to operate. They are charged by a crane or derrick operating a clamshell and loading from stock piles, by a conveyor, or the plant can be set below the ground or in a basement and the bin filled by dumping from trucks.

On road work the plant is set up at the siding or gravel pit, and the batchers discharge into trucks which carry a load of aggregate and cement in the right proportions to the mixer, which may be some miles away. They are used also for permanent mixing plants, in this case the concrete being transported where desired.

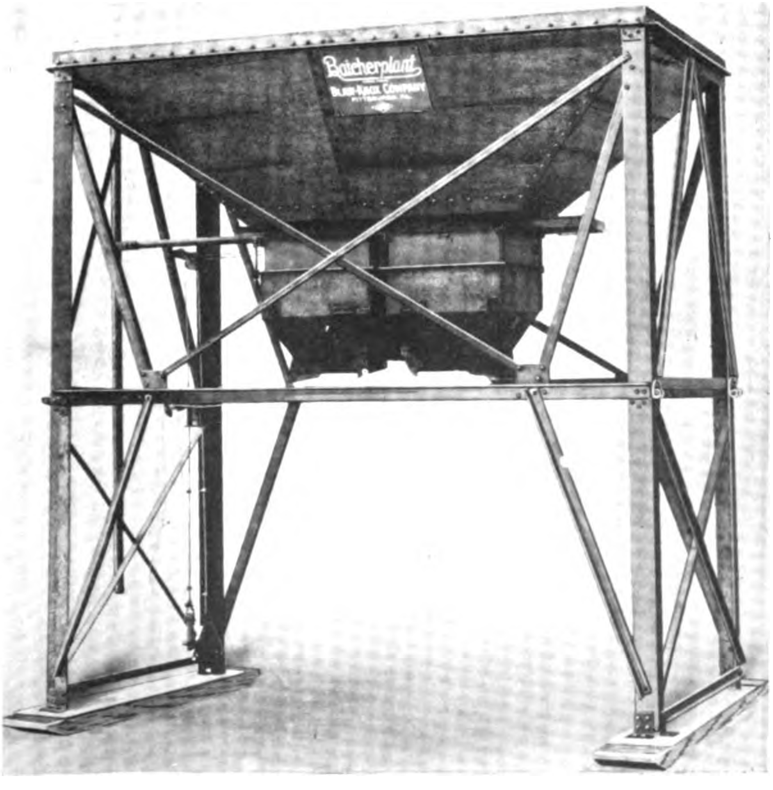

Fig. 11.—Batcher Plant Erected.

Apart from any question of uniformity and strength a batcher plant represents great economy in handling materials. One operator for the derrick will replace 12 men wheeling sand and stone to a $\frac{3}{4}$ cu. yd. mixer. One man is all that is required to operate the batcher plant and the mixer, and with one or two men on the cement the whole concrete making force is reduced to three or four men.

Measuring Sand by the "Inundator."

To eliminate adjustments to the sand batcher and water tank to compensate for bulking and water content, the "sand inundator" was invented. This is based on the principle that sand when completely inundated has the same volume as when dry, and it replaces the sand batcher in the batcher plant.

Its essential parts are a sand-measuring container with adjustable bottom, a water-charging tank, an excess-water tank, a shaker or sand sifter, and a strike-off gate. The sand container is adjustable, as before, to contain the volume required of *dry* sand. The total amount of water required per batch is calculated as before, assuming dry sand. The water charger is set to contain the amount of water required to inundate the sand—a fixed quantity so long as the same sand is used and equal to the voids in the sand—and the excess-water tank is set to hold the difference between this amount and the total amount required.

The operation is as follows: The main-line water-valve is opened, filling the charging tank, the overflow passing through an overflow pipe to the excess-water tank, and when this tank begins to overflow the valve is shut off. The two tanks then hold exactly the required amount of water for the batch. The valve controlling the water charger is then opened, allowing the water to drain into the

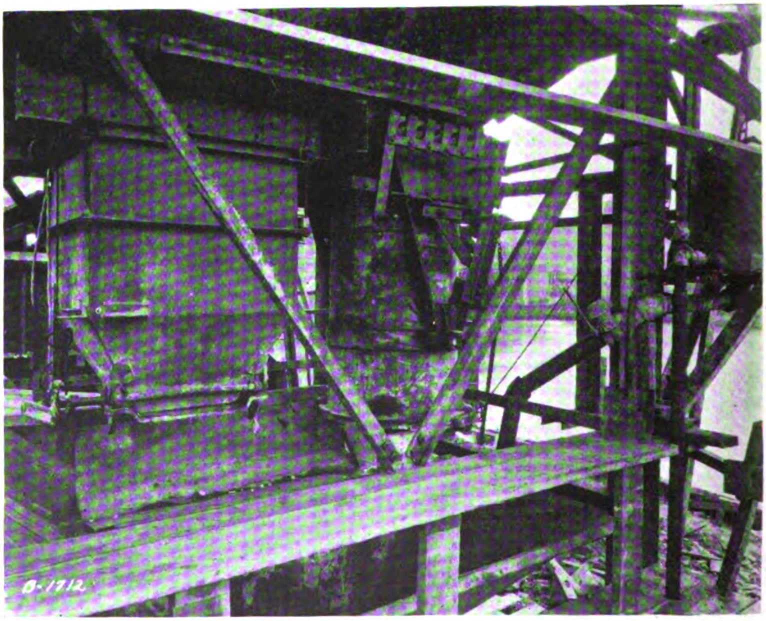

Fig. 12.—Sand Inundator (on right) and Stone Batcher attached to Steel Bin.

inundator or sand container, and the operator sifts the sand into the container by means of the shaker gate—this is to give complete inundation. If there is any excess water in the inundator above that required for inundation, it escapes at the overflow.

When the inundator is full of sand, the level is struck off, a latch is released, and the sand and water automatically dump into the mixer. The excess-water tank valve is then opened, and this water discharges directly into the mixer. The whole operation takes less than 45 seconds, which is less than the time required for mixing.

The stone batcher is operated in the ordinary way by a lever.

The inundator is mounted on trunnions and is self-righting when empty. *Fig.* 12 shows a sand inundator on the right-hand side with a stone batcher, and *Fig.* 13 a batcher plant with an inundator attached on the right-hand side, both attached to a steel bin.

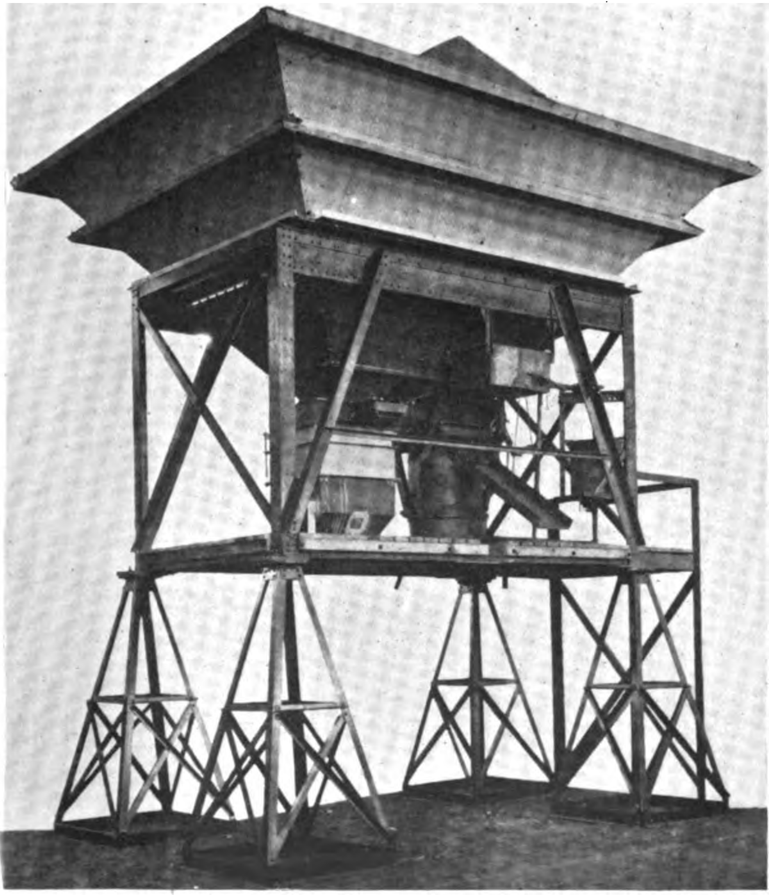

Fig. 13.—Large Central Proportioning Batcher Plant with Stone Batcher and Sand Inundator.

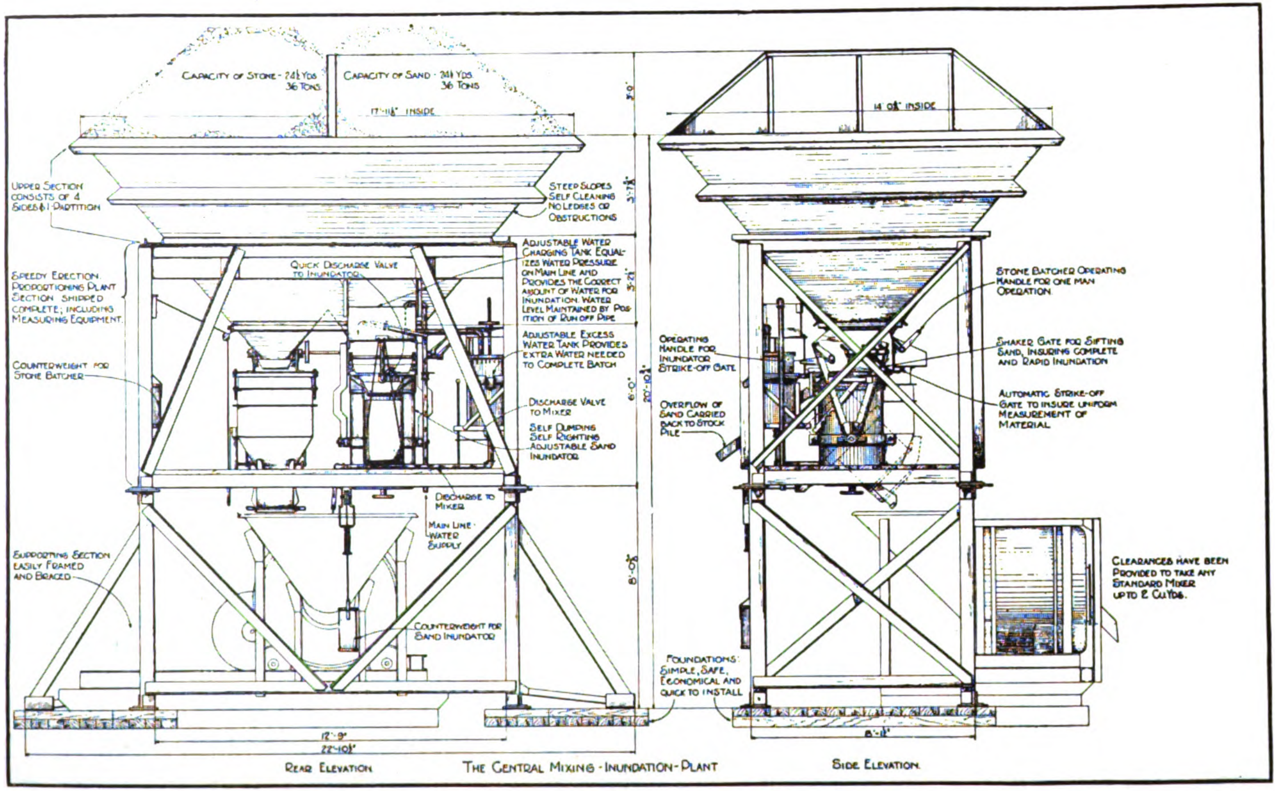
Capacity of Stone - 24½ Yds 36 Tons
Capacity of Sand - 24½ Yds 36 Tons
17'-11⅛" inside
14'-0⅛" inside
Upper Section consists of 4 Sides & 1 Partition
Steep Slopes Self Cleaning No Ledges or Obstructions
Speedy Erection Proportioning Plant Section shipped complete; including Measuring Equipment.
Quick Discharge Valve to Inundator
Adjustable Water Charging Tank Equalizes Water Pressure on Main Line and Provides the Correct Amount of Water for Inundation. Water Level Maintained by Position of Run off Pipe
Adjustable Excess Water Tank Provides Extra Water needed to Complete Batch
Counterweight for Stone Batcher
Discharge Valve to Mixer
Self Dumping Self Righting Adjustable Sand Inundator
Discharge to Mixer
Main Line Water Supply
Supporting Section easily Framed and Braced
Counterweight for Sand Inundator
3'-0"
3'-7⅜"
3'-2½"
6'-0"
8'-0⅜"
20'-10½"
12'-9"
22'-10½"
8'-1½"
Operating Handle for Inundator Strike-off Gate
Overflow of Sand Carried back to Stock Pile
Stone Batcher Operating Handle for one man Operation
Shaker Gate for Sifting Sand, insuring complete and Rapid Inundation
Automatic Strike-off Gate to insure uniform Measurement of Material
Clearances have been provided to take any Standard Mixer up to 2 Cu.Yds.
Foundations: Simple, Safe, Economical and Quick to install
Rear Elevation
The Central Mixing - Inundation - Plant
Side Elevation

Fig. 14.—Central Mixing and Inundation Plant.

Fig. 14 shows the various parts of a central mixing-inundation-plant. The inundator automatically eliminates the greatest variable in proportioning ; that is, the bulking of the sand and the water contained in the sand. The bulking of coarse aggregate is negligible, and the water contained not very great ; it can be calculated for average conditions and occasional checks made after heavy rain.

This system thus affords a complete automatic control over all the constituent materials in the concrete, so that uniformity must necessarily follow. No changes are necessary to the plant until either a different strength or slump is desired or the aggregates are changed.

Small inundators are made to be used on small jobs where measurement is by wheelbarrow. The wheelbarrows are emptied into the inundator, which is on the ground, and this discharges into the hopper, only the excess amount of water required being added by pail.

Mixing and Curing.

The mixing of each batch should take not less than one-and-a-half minutes, and preferably two minutes, or even longer if possible. Increased period of mixing increases the uniformity and adds to the strength.

Absorption of moisture by the forms and evaporation from the surface of the concrete after the forms are stripped will cause some of the mixing water essential to the hardening processes to be lost, and the concrete will not attain its full strength. If the forms are not oiled they should be well drenched with water just before pouring. Horizontal surfaces should be covered with damp sand or shavings for several days. Vertical surfaces should be sprinkled with a hose continually, or covered with canvas or burlap kept soaked with water. This is particularly important when the surfaces are exposed to the sun. In freezing weather the concrete should be cured with steam.

Curing should be done for at least 10 days, and longer if possible ; surfaces subject to wear, such as floors and roads, should be cured for three weeks. Curing, though not costing very much, is too often entirely neglected, with the result that though every precaution has been taken up to the time of depositing, the concrete will not attain its maximum strength.

Advantages of Control Methods to the Engineer.

It is hardly necessary to point out to the engineer the advantages of " field control " of concrete mixtures. He will be able to design for any strength desired and be sure of getting it consistently, all hitherto uncontrollable factors being eliminated. He can use higher stresses, and design more economically. All arguments with the contractor—and they are many—will be avoided.

Advantages to the Contractor.

The advantages to the contractor must be shown him in money saved. A moderate investment in plant—the cost of which can often be saved on two or three jobs—will place him ahead of his competitors, both in the cost of his work and his reputation for doing the best work possible.

If he is going to chute his concrete, the consistency will be so uniform that there will be no blocked chutes from dry batches (always a source of trouble and lost time), and no segregation, so that the labour of working the concrete in the forms is lessened. Better surfaces will be obtained, requiring less rubbing. He will be using the minimum possible amount of cement for the strength required; it is not difficult to save 6 to 7 per cent. of the cement compared with what would be used by the old methods. He can often use local materials by correctly proportioning the fine and the coarse aggregate, whereas otherwise he may have to transport materials from a distance, at much greater cost.

Being a mechanical operation the cost can be calculated much more closely, and the worry always connected with hiring labour is largely eliminated.

Finally, the contractor will have the satisfaction of giving the owner a structure the strength of which cannot be questioned.

Introducing "Field Control."

Thirty years' experience of "1 : 2 : 4," wheelbarrow measurements, and "water as you like it" cannot be thrown over in a day or a year. Change must come by education, and the initiative must be taken by those at the head of their professions whether they be architects, engineers or contractors. The technical press can do a great deal by publishing the results obtained where field-control methods are used. In the United States it is the leading topic amongst those engaged in concrete construction. Classes for those interested are being formed in several of the large towns, sponsored by engineering and technology clubs, to study the subject under an expert lecturer. Contracting firms and engineering departments of cities and commissions are issuing printed instructions to their field forces. There is no doubt that in a very short time up-to-date engineers will specify "field control," and the contractors will use it as a matter of choice.

The design curves in this article have been taken from a Bulletin issued by the American Portland Cement Association on the "Design and Control of Concrete Mixtures." This Bulletin also gives the general principles of designing mixtures and the method of proportioning aggregates by their fineness moduli. For photographs of mechanical measuring devices the author is indebted to the Blaw-Knox Co.

CORRECTION.—An error occurred in the notes beneath *Fig.* 2 in Part 1 of this article (*C. and C.E.*, June, 1926). The values given were not percentages, as stated, but definite amounts.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ¼ in. mesh	,,	15	6
Thames ballast	,,	10	6
Broken brick (¾ in.)	,,	11	6
Best British Portland Cement	per ton 58s. to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	,, 100s. to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £20 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
7/16 in. to ½ in. Rounds	,,	10	9
⅜ in. Rounds	,,	11	0
¼ in. Rounds	,,	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per foot cube	1	11
Do.	do.	in columns	,, ,,	2	1
Do.	do.	in beams	,, ,,	2	3
Do.	do.	in floor slabs 4 in. thick	per yard super	6	0
Do.	do.	in floor slabs 5 in. thick	,, ,,	7	6
Do.	do.	in floor slabs 6 in. thick	,, ,,	9	0
Do.	do.	in floor slabs 7 in. thick	,, ,,	10	6
Do.	do.	in walls 6 in. thick	,, ,,	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level. Add for "Ferrocrete" 1s. 10d. per yard cube.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
,, 7/16 in. to ½ in.	,,	21	6
,, ⅝ in. to 2⅞ in.	,,	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½d.; ⅜-in. rods, 1d.; ½-in. rods, 1¼d.; ⅝-in. rods, 1½d.; ¾-in. rods, 1¾d.; ⅞-in. rods, 2d.; 1-in. rods, 2¼d.; 1¼-in. rods, 3d.; 1½-in. rods, 3½d. (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1d.; ⅜ in., 2d.; ½ in., 2½d.; ⅝ in., 3d.; ¾ in., 3½d.; ⅞ in., 4d.; 1 in., 4½d.; 1¼ in., 6d.; 1½ in., 7d. (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	,, ,,	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	,, ,,	1	1½
Do. do. as last, in narrow widths	,, ,,	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	,, ,,	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

The Action of Sugar on Cement Mortar.

Two recent cases in Egypt of failures of concrete in districts where sugar is very plentiful have led M. C. Tsountas to investigate the action of sugar on cement mortar. In the first case the concrete set very slowly and on the removal of the shuttering after a delay of 7 days the lower portion of the concrete was found to be soft. The whole mass contained dangerous cracks and the work was condemned. The cement employed satisfied all the usual tests and when the work was reconstructed, using the same cement and every possible care, it gave complete satisfaction.

The second failure was in a sugar-works where some hundreds of tons of cement had been used without a hitch for the construction of a reinforced concrete building. One small pillar failed to set but, on reconstruction with the same cement, the concrete in this pillar was as good as in the rest of the building. Thus in neither case could the failure be attributed to inferior cement.

It is known that the lime combines with sugar in solution to form saccharates of lime, so that if there is sugar in the water used for gauging mortar it will dissolve the lime set free and form saccharates. In this way the cement is attacked and may be disintegrated if there is sufficient sugar present.

In a reinforced concrete building in Copenhagen certain portions of the concrete, a 1 : 2 : 3 mixture with Danish cement, did not harden, although the rest of the concrete was excellent. In the concrete which had not hardened sugar was found to be present at the rate of 2 parts per 100 parts of cement. The presence of sugar was due to the cement having been packed in sugar bags.

M. Tsountas experimented with two samples of artificial Portland cement and tested each of them for setting time, Le Châtelier test, and tensile strengths both neat and in 1 : 3 mortar. The gauging water used had varying quantities of sugar dissolved in it.

RESULTS OF TESTS

Artificial Portland Cement S/40

Water.	Setting Time. Initial.	Setting Time. Final.	Le Châtelier Test.
Pure	86 mins.	240 mins.	0·5 mm.
Water with ·1% sugar	60 ,,	210 ,,	0·5 ,,
,, ,, ·2% ,, ...	53 ,,	175 ,,	2·5 ,,
,, ,, ·3% ,, ...	46 ,,	155 ,,	7·0 ,,
,, ,, ·4% ,, ...	35 ,,	105 ,,	5·0 ,,

Artificial Portland Cement S/32

Water.	Set (minutes).		Le Châtelier. mm.	Tension (lbs. sq. inch.).			
				Neat.		1 : 3 Mortar.	
	Initial.	Final.		7 days.	28 days.	7 days.	28 days.
Pure	45	130	0·5	571	634	298	375
Water with 0·5% sugar . . .	3	7	5·5	546	578	234	281
,, ,, 1% ,, ...	5	8	12·5	472	499	178	203
,, ,, 2% ,, ...	7	27	19·0	Briquettes disintegrated.			
,, ,, 3% ,, ...	7	36	20·0				
,, ,, 4% ,, ...	7	45	20·0				

The results may be summarised as follows:—The presence of sugar in cement mortar

(1) Considerably accelerates the setting time.

(2) Destroys the resistance to the Le Châtelier test.

(3) Lowers the strength of the mortar in proportion to the amount of sugar present.

In Egypt and other countries where workmen are fond of sugar cane considerable risk occurs of contamination of the gauging water by the sugar on their hands or by pieces of sugar cane thrown into the tanks.—*Revue des Matériaux de Construction.*—*W.S.G.*

Prospective New Concrete Work.

ABERBEEG.—*Bridge.*—The G.W.R. proposes to build a bridge at Aberbeeg, at a cost of nearly £20,000.

ALDERSHOT.—*Houses.*—The T.C. has instructed the Surveyor to prepare plans for the erection of 144 houses.

ANSTEY.—*Houses.*—The Barrow-on-Soar R.D.C. proposes to erect 82 houses in the surrounding parishes.

BARKING.—*Culvert.*—A culvert is to be constructed at Mayesbrook.

BARNET.—*Houses.*—The R.D.C. proposes to build 57 houses by direct labour.

BECKENHAM (KENT).—*Concrete Houses.*—The U.D.C. has accepted a tender for the construction of 60 concrete houses.

BRADFORD. — *Houses.* — The Corporation proposes to spend £250,500 on the construction of 594 houses on the Swaine House estate.

BRISTOL.—*Bridge.*—The City Engineer has been instructed to report on a proposal to erect a bridge near St. Philip's Marsh.

CHELMSFORD.—*Wall.*—A retaining wall is to be constructed on a section of the Chelmsford-Danbury Road.

CHERTSEY.—*Houses.*—The U.D.C. has applied for permission to borrow £29,000 for housing purposes.

CLAY CROSS.—*Reservoir.*—The U.D.C. proposes to construct a 1,000,000-gallon reservoir.

CLUTTON.—*Houses.*—The R.D.C. has applied for sanction to borrow £30,500 for housing purposes.

CLYDACH.—*Footbridge.*—A footbridge is to be constructed at the Forge, Clydach.

COLNE.—*Houses.*—The T.C. is considering a scheme for the erection of 60 houses on the Judge Fields estate.

DARTFORD.—*Houses.*—The U.D.C. is considering a scheme for the construction of 200 houses in Lowfield Street.

DIDCOT.—*Houses.*—The Wallingford R.D.C. proposes to build 44 houses at Didcot.

DISS.—*Concrete Road.*—The U.D.C. has instructed the Surveyor to prepare plans for constructing a concrete road in Victoria Road.

DUDLEY. — *Houses.* — The Weetslade R.D.C. is negotiating for a site on which to erect 60 houses.

EASTBOURNE.—*Rink.*—The T.C. proposes to spend £2,000 on the construction of a concrete skating rink at Fisherman's Green.

EASTLEIGH.—*Houses.*—The U.D.C proposes to erect 85 houses, estimated to cost £33,739.

ELLESMERE PORT. — *Houses.* — The U.D.C. has instructed the Surveyor to prepare plans for the erection of 500 houses.

ESHER AND THAMES DITTON.—*Houses.*—The U.D.C. proposes to build 114 houses.

FALMOUTH.—*Houses.*—The Corporation is considering a scheme for the construction of 99 houses.

FARNHAM.—*Houses.*—The U.D.C. proposes to purchase 10 acres of land on which to erect 60 houses.

GARSTANG.—*Bridge.*—A bridge is to be constructed across the River Wyre.

GODALMING.—*Houses.*—The T.C. proposes to erect 44 houses at Broadwater.

HARROGATE.—*Houses.*—The T.C. has applied for sanction to borrow £26,680 for the erection of 46 houses on the Ripon Road estate.

HASTINGS. — *Concrete Groynes.* — The T.C. has applied for permission to borrow £14,500 for the construction of concrete groynes.

HECKMONDWIKE. — *Houses.* — The U.D.C. is considering a scheme for the erection of 36 houses on the Stubbley estate.

HEMSWORTH.—*Houses.*—The R.D.C. is considering a scheme for the construction of 30 houses.

HORSHAM.—*Houses.*—The U.D.C. proposes to build 69 houses at Spooners Farm.

HORSFORTH.—*Houses.*—The U.D.C. is considering a scheme for building 100 houses at Cragg Hill.

HOVE.—*Houses.*—The Corporation has purchased 53 acres of land for housing purposes.

KILLESTER.—*Road.*—A road is to be constructed from Killester to Malahide, Dublin.

LLANDUDNO.—*Road.*—A road is to be constructed from Deganwy to Llandudno.

MANCHESTER.—*Culvert.*—A culvert is to be constructed at Platt Brook. The cost is estimated at £11,000.

NORTHAMPTON. — *Houses.* — The T.C. proposes to erect 50 houses on the Duston estate.

PARHAM. — *Concrete Bridge.* — The Plomesgate R.D.C. is considering a scheme for the construction of a reinforced concrete girder bridge at Parham.

PERTH.—*Houses.*—The T.C. has applied for sanction to borrow £70,000 for housing purposes.

PEWSEY.—*Houses.*—The R.D.C. proposes to erect 60 houses in various parts of the district.

POOLE.—*Houses.*—The T.C. is recommended to erect 100 houses.

PRESCOT.—*Road.*—A road is to be constructed from Driffield Road to Brook Bridge. The cost is estimated at £2,000.

RICHMOND (YORKS).—*Reservoir.*—The T.C. proposes to construct a 1,000,000-gallon reservoir.

ST. IVES.—*Houses.*—The T.C. has prepared a scheme for the construction of 50 houses.

SEDBERGH.—*Concrete Reservoir.*—The R.D.C.'s water supply scheme provides for the construction of a reinforced concrete reservoir.

SHIPLEY.—*Concrete Retaining Wall.*—The T.C. proposes to construct a reinforced concrete retaining wall at Thackley Old Road.

SHOREHAM.—*Sea Defence Works.*—A sum of £2,050 is to be spent on sea defence works.

SKELLOW.—*Houses.*—The Adwick-le-Street U.D.C. has applied for sanction to borrow money for erecting 60 houses at Crossfield Lane, Skellow.

SOMERSET.—*Road.*—The County Council proposes to spend £18,000 on the construction of a by-pass road at Crowcombe.

SOMERSET.—*Revetment.*—The County Council proposes to spend £2,500 on extending the reinforced concrete revetment at the western end of Blue Anchor.

SOUTHWOLD.—*Sea Defence Works.*—The T.C. has applied for sanction to borrow £7,000 for sea defence works.

STAFFORD.—*Houses.*—The T.C. proposes to spend £28,000 on the erection of 65 houses.

STALYBRIDGE.—*Houses.*—The T.C. proposes to erect 250 houses on the Hague estate.

STOCKTON.—*Houses.*—The T.C. has submitted a scheme to the M.H. for the construction of 152 houses on the Mount Pleasant estate.

STOKE-ON-TRENT.—*Houses.* — Application has been made for sanction to a loan of £15,900 for the erection of 38 houses in Fletcher Road.

STRATFORD-ON-AVON.—*Concrete Houses.* The Corporation proposes to erect two concrete houses by direct labour. The cost is estimated at £705.

SUTTON COLDFIELD. — *Houses.* — The T.C. has applied to the M.H. for sanction to erect 38 houses in Tower Road.

TONBRIDGE.—*Houses.*—The U.D.C. has applied for sanction to erect 90 houses at Cage Green and Shipbourne Road.

TROWBRIDGE.—*Houses.*—The U.D.C. is negotiating for the purchase of 7½ acres in Holbrook Lane for the erection of 90 houses.

UXBRIDGE.—*Houses.*—The Council is considering a scheme for erecting 50 houses on the Meadow Estate.

WALSALL.—*Bridge.*—A bridge is to be constructed at Walsall.

WEST HARTLEPOOL. — *Houses.* — The Corporation has applied for permission to erect 500 houses on the Rift House estate. The cost is estimated at £70,500.

WHITEHAVEN.—*Houses.*—A scheme is being considered for the erection of 170 houses on the Branstey and Arrowthwaite estates.

WIGAN.—*Houses.*—The T.C. proposes to build 98 houses by direct labour.

WOKING.—*Houses.*—The U.D.C. proposes to build 60 houses.

WORKSOP.—*Houses.*—The U.D.C. is to erect 52 houses.

WORSLEY.—*Houses.*—The U.D.C. proposes to build 50 houses.

WREXHAM.—*Houses.*—Application has been made for permission to build 50 houses.

Tenders Accepted.

BARKING (LONDON).—*Paving Slabs.*—The U.D.C. has accepted the tender of the Patent Victoria Stone Co., Ltd., at 6*s.* 2*d.* per sq. yd., for the supply of 300 sq. yds. of artificial stone paving. Other tenders submitted were: E. Matthews & Co., 6*s.* 1*d.*; Alexandra Paving Stone Co., 6*s.* 3*d.*; Rom River Co., 6*s.* 9½*d.*; Brookes, Ltd., 7*s.*

BARKING. — *Concrete Piles.* — Messrs. Concrete Piling, Ltd., have secured the contract for constructing and driving about 1,800 reinforced concrete piles for the extension of the Barking Power Station.

BRIDLINGTON.—*Promenade.*—The T.C. has accepted the tender of Messrs. Holliday & Barker, at £999 2*s.*, for reconstructing in concrete the promenade from the Opera House to the north entrance of the Spa.

GRANGE-OVER-SANDS.—*Concrete Reservoir.*—The U.D.C. has accepted the tender of Messrs. A. Nelson & Sons, Grange-over-Sands, at £923, for the construction of a mass concrete reservoir with a capacity of 200,000 gallons.

HAVERFORDWEST.—*Concrete Carriageway.*—The Corporation has accepted the tender of Messrs. Fothergill Bros., Ltd., at £2,129 14*s.* 9*d.*, for the construction of 1,800 super yards of 6-in. reinforced concrete carriageway, 980 super yards of concrete footway, and 400 lineal yards of stone kerbing. Other tenders submitted were: W. H. Hawkins, £4,634 13*s.*; D. Strahon & Sons, £3,848 15*s.* 7*d.*; J. E. Jones, £3,119 10*s.* 6*d.*; E. N. Farley, £2,951 14*s.*; W. J. Williams, £2,504 12*s.*; W. Ewart Evans, £2,095 3*s.* 9*d.*

ILKESTON.—*Concrete Water Tower.*—The Corporation has accepted the tender of the Yorkshire Hennebique Contracting Co., Ltd., for the erection of a reinforced concrete water tower.

KENSINGTON (LONDON). — *Concrete Jetty.*—The B.C. has recommended for acceptance the tender of Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd., at £1,153, for the construction of concrete decking at Lots Road Wharf. Other tenders submitted were: Industrial Constructions, Ltd., £1,858; Peter Lind & Co., £1,390; Saxild & Partners, £1,250; F. Bradford & Co., £1,240; K. Holst & Co., £1,230.

LEWISHAM (LONDON).—*Concrete Tubes.*—The B.C. has accepted the tender of Messrs. J. Smith Bros., Ltd., at 4*s.* 4*d.* per foot run, for the supply of 400 ft. of 18-in. concrete tubes.

LIVERPOOL. — *Concrete Houses.* — The Corporation has accepted the tender of Messrs. Henry Boot & Sons for the construction of 1,000 concrete houses.

PENWERRIS. — *Concrete Houses.* — The Falmouth T.C. has provisionally accepted the tender of Mr. J. H. Lobb, of Mevagissey, at £39,390 15*s.*, for the erection of 99 concrete houses.

POTTERS BAR.—*Concrete Culvert.*—The South Mimms R.D.C. has accepted the tender of Mr. A. M. Turner, at £308 10*s.*, for the construction of a reinforced concrete culvert at Baker Street, Potters Bar. Other tenders submitted were: Turner & Co., £319; Hicks & Reid, £348; London County Public Works, Ltd., £368; Earlsfield Construction Co., £709; Peter Lind & Co., £720.

RATHFADDEN.—*Concrete Tank.* — The Waterford T.C. has accepted the tender of Mr. F. J. McCann, at £255 15*s.*, for the construction of a 5,000-gallon reinforced concrete tank.

ROSEHARTY. — *Concrete Tanks.* — The T.C. has accepted the tender of Mr. A. Wiseman, Fraserburgh, at £1,268, for the construction of reinforced concrete sedimentation tanks.

DUCKHAM'S
CONCRETE
MOULD
OIL

GOES FARTHEST
FUNCTIONS BEST

ALEXANDER DUCKHAM & Co., Ltd.
6 BROAD ST. PLACE, LONDON, E.C.2

SHEFFIELD.—The T.C. has accepted the tender of Messrs. T. Wilkinson & Sons, Ltd., at £18,467, for reinforced concrete work at the Tenter Street Depot.

STOKE-ON-TRENT. — *Concrete Tank.*— The T.C. has accepted the tender of Mr. P. Pemberton, Furlong Road, Tunstall, at £1,836, for the construction of a reinforced concrete tank.

WIMBLEDON (LONDON). — *Concrete Bridge.*—The T.C. has accepted the tender of Messrs. J. Garrett & Sons, at £1,799, for the construction of a reinforced concrete bridge at Ashcombe Road.

WIMBLEDON (LONDON). — *Concrete Houses.*—The T.C. has accepted the tender of the Triangular Construction Co., at £415 per house, for the construction of 60 houses on the Durnsford estate.

WINDSOR.—*Concrete Tank.*—The T.C. has accepted the tender of Messrs. Holst & Co., at £569, for the construction of a reinforced concrete water tank at Leonards Hill.

ANNOUNCEMENT.

Messrs. L. G. MOUCHEL & PARTNERS, Ltd., Civil Engineers, 36/38 Victoria Street, S.W.1, beg to announce that they have now dispensed with their system of licensing contractors to carry out ferro-concrete construction to their designs. All Licences have either been cancelled or notices terminating them have been sent.

As ferro-concrete construction is now so widely employed, Messrs. L. G. Mouchel & Partners, Ltd., are of the opinion that the original object of licensing contractors (namely, that of ensuring that only such contractors who specialised in this form of construction executed works to their designs) no longer exists.

Trade Notices.

Mixers for India.—The Ransome Machinery Co. (1920), Ltd., have secured an order for two further 1 cu. yd. size rotary drum concrete mixers, electrically driven, for the Sutlej Valley Irrigation Project, India. This now makes a total of fourteen 1 cu. yd. mixers, which this firm has supplied for work on this scheme.

Change of Address.—The British Reinforced Concrete Engineering Co., Ltd., having recently removed their head office and works from Manchester to Stafford, have now opened a branch office for Lancashire at their old Manchester address, No. 1 Dickinson Street. This will take the place of the Liverpool office, which was previously used as the branch office for Lancashire.

Change of Address.—Messrs. Richard Hill & Co., Ltd., have transferred their London office to No. 3 Victoria Street, Westminster, S.W.1. Mr. Arthur Campling has taken over the London representation.

New Winch Catalogue.—A new catalogue of their well-known "Zenith" friction winches has been issue by the British Steel Piling Co., Ltd., of 54A Parliament Street, S.W.1, copies of which will be sent post free to those interested on request. These winches are made in a variety of sizes, for electric, petrol, paraffin, or crude oil drive, and have lifting speeds from 50 to 600 ft. a minute. The catalogue contains complete particulars of the different types of "Zenith" winch, and a number of excellent illustrations of these machines in operation on various important works.

Books.—The McGraw-Hill Publishing Co., Ltd., of 6, Bouverie Street, E.C.4, have issued a new list of their well-known books on civil engineering, copies of which will be sent free on request. The books are practically all by American authors, and embody the latest practice in construction in that country. All branches of civil engineering and building construction are covered.

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CONCRETE
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CONSTRUCTIONAL ENGINEERING

SEPTEMBER 1926 **VOL. XXI No. 9**

CONCRETE SERIES No1

TWENTY-FIRST YEAR OF PUBLICATION

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CONCRETE
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Volume XXI. No. 9. LONDON, SEPTEMBER, 1926.

EDITORIAL NOTES.

Effect of Sea Water on Portland Cement Concrete.

AMONG the advantages claimed for aluminous cement is that it is immune from attack by sea water, and the emphasis that has been laid on this claim by manufacturers of the new cement has tended to raise doubts as to whether Portland cement is safe to use in contact with sea water.

It is true that the inventor of aluminous cement, when he made his fortunate discovery, was seeking to produce a cement that would resist the action of waters highly impregnated with sulphates which occur in the soil of the South of France and Algeria. The experience up to that time had been that Portland cement concrete would not withstand the action of such water. It must be kept in mind, however, that the need for such a special cement was experienced in the early years of this century when the science of concrete making, and to a lesser extent of cement making also, was in its infancy. Hence, while the Portland cement concrete of 1903 was found to be deficient in its resistance to highly-sulphated waters, it is not impossible that the concrete of 1926, made with better cement, clean aggregate scientifically graded, and well mixed with no excess of water, might be successful in resisting the action of sulphate water.

Sea water contains sulphates, although to a much smaller extent than the sulphated soil waters of France and Algeria, and hence it was natural that the manufacturers of aluminous cement should claim it to be immune from attack by sea water. Any implication, however, that Portland cement concrete will not resist the action of sea water is obviously refuted by reference to the large number of docks, jetties, wharves, and other constructions to be seen round the coasts of the world, such structures having stood the test of time. Yet at the same time the technical press occasionally contains records of experimental work tending to show that under certain conditions Portland cement concrete is attacked by sea water, and the usual object of such investigations has been to ascertain the conditions which interfere with the successful application of Portland cement concrete to sea-water work.

The use of concrete in sea water seems to have been a case where practice preceded experiment, and maritime concrete works were constructed with satisfaction before chemists began to investigate in the laboratory the chemical effect of sea water upon Portland cement. It is perhaps inevitable with so large a number of sea-water concrete constructions that there should be a few cases of failure, and that such cases of failure should receive prominence out of proportion to their importance compared with the aggregate use of concrete in sea water. In the British Isles the notorious failure of concrete at Aberdeen Harbour in 1887 was the subject of much discussion, and more especially so because the first conclusion arrived at was erroneous and was corrected after further investigation. The chemists concerned with the investigation found that the destroyed concrete contained an undue proportion of magnesia, and the conclusion drawn was that the cement had contained an excess of magnesia and was consequently the cause of the disintegration of the concrete. Subsequent investigations showed that the magnesia found in the destroyed concrete had been derived from the sea water and was not originally present in the cement, and this led to the conclusion that the real cause of destruction was the porosity of the concrete permitting the entrance of sea water and the displacement of lime in the cement by magnesia from the sea water.

The chemical investigation of the effect of sea water on Portland cement is entitled to be described as classical, and was the work of Candlot in Paris, who in 1897 propounded the theory based on experimental evidence that when the calcium aluminate which is present in Portland cement comes into contact with the sulphates in sea water there is formed a compound—calcium-sulpho-aluminate—which swells on crystallisation, and if this swelling takes place inside a mass of concrete, i.e. in any voids that exist, there is a risk of bursting and disintegration. The theory has been so universally accepted that calcium-sulpho-aluminate is known as "Candlot salt" or "Candlot bacillus." It will be obvious that the deleterious action of sea water upon Portland cement concrete can only occur if the sea water can penetrate the interior of the concrete, and hence it is now accepted that a *sine qua non* of successful sea-water concreting is a dense impermeable concrete such as can readily be obtained by proper proportioning and mixing. On the Continent it is not unusual to include trass, pozzuolana, or gaize as one of the constituents of concrete for sea-water work as a means of securing density and impermeability. These materials consist of clay which has been heated by volcanic agency, and they are claimed to contain silica in an active form which can combine with the lime set free in the cement during setting. Such pozzuolanic materials do not exist in Great Britain and are consequently not used.

The modern advances in the science of concrete-making have caused the preparation of impermeable concrete to be a simple matter, so that the problem of producing a safe and enduring structure of Portland cement concrete in sea water may be said to have been solved. Bearing in mind the improvements in the quality of cement and in the science of concrete production that have occurred since maritime concrete works were commenced, it is indeed surprising that some of the earlier concrete works round the coasts are existing at the present time.

The manufacture of cement of the soundness which is now the standard, and the necessity for a dense impermeable concrete, were not realised fifty years ago, and we must either assume that such constructions have existed by reason of fortuitous favourable circumstances, or that the devastating effects of sea water upon permeable concrete suggested by laboratory experiments do not actually occur in practice.

On the practical side there is valuable evidence upon the behaviour of Portland cement concrete in sea water to be obtained from a report by the Engineer-in-

Chief of the Admiralty which is embodied in a publication of the Department of Scientific and Industrial Research entitled, "The Deterioration of Structures in Sea Water." This report sets out in tabular fashion the broad details of construction and the present condition of more than thirty reinforced concrete jetties constructed by, or for, the Admiralty at various times since 1902. The following statement is made : "This report deals only with the defects which have appeared in Admiralty reinforced concrete jetties to the almost complete exclusion of any reference to the merits of this form of construction ; the merits are nevertheless very real and fully appreciated by those who have had experience in this type of construction." The reasons assigned for such defects as have occurred include damage by collisions, rubbish left in formwork before concreting, and bad workmanship—these being causes which have no connection with the merits of Portland cement concrete in resisting sea-water action. The unfavourable conditions which have an interest from a technical standpoint are :—

(1) Insufficient cover of steel reinforcement by concrete either in design or through accidental displacement of steel during concreting.

(2) Porous concrete.

(3) Unsuitable types of reinforcement.

(4) Stray electric currents giving rise to electrolysis.

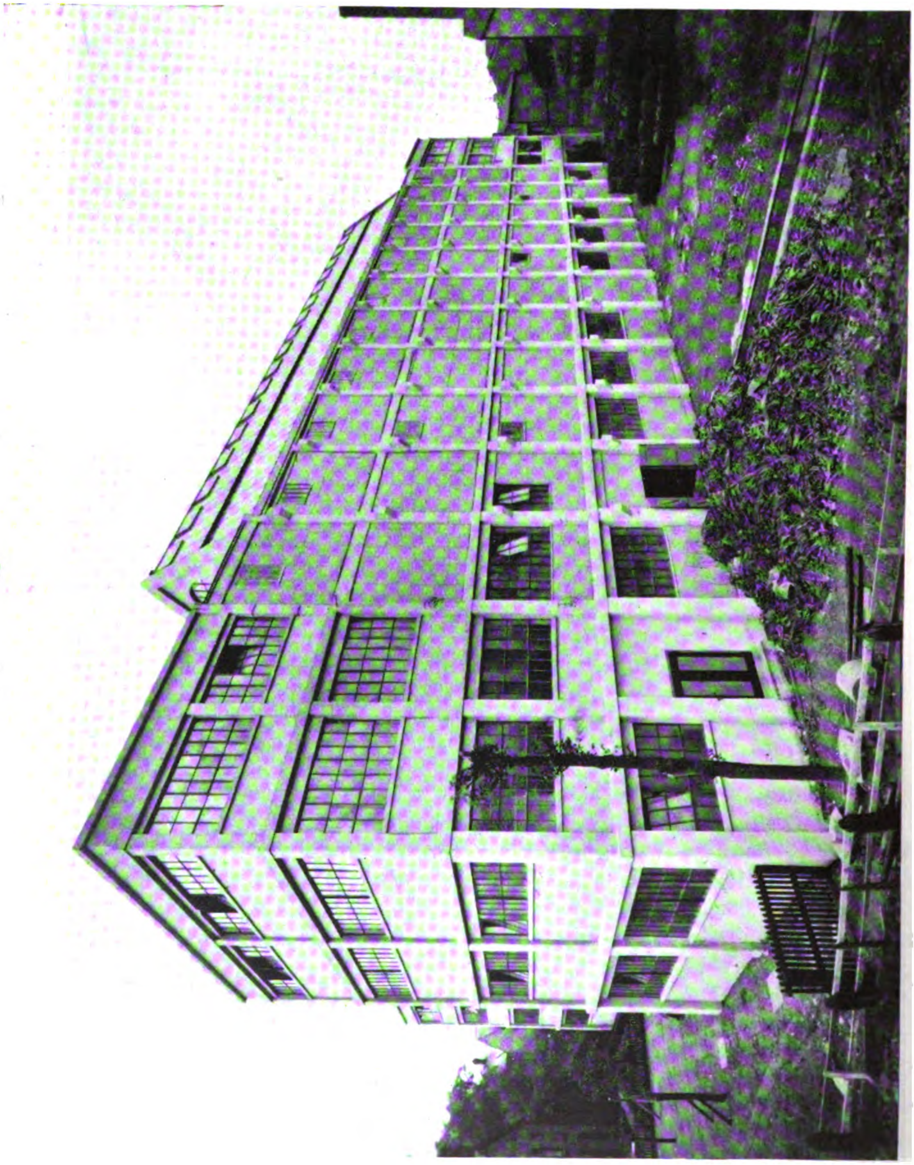
It is obvious that these are conditions which can be avoided, and it is therefore justifiable to assert that Portland cement is a safe material to use for marine work. The Admiralty report as a whole, based as it is on careful observations on a number of constructions of various ages, warrants increased confidence in the ability of Portland cement concrete structures to resist the action of sea water provided certain well-defined conditions are observed.

Prehydration of Cement in Concrete Mixing.

A METHOD has been patented in the United States by which concrete is mixed in two stages. In the first operation the cement is mixed with the water, and in the second operation this slurry and the other ingredients are mixed together. This method was used on the construction of a water filtration plant for the Baltimore Bureau of Water Supply, and it is stated that very satisfactory results were obtained. It was found that by the method used twelve seconds was sufficient time for mixing the cement with water, and that fifteen seconds was sufficient for thoroughly mixing the slurry with the aggregate, while tests on specimens cut from the finished concrete showed strengths as high as those usually obtained by more usual methods of mixing.

The cement and water are mixed in a cylindrical drum with a vertical axis. Water enters the drum at the top in predetermined quantities, leaves it through a pipe at the bottom, and again enters at the top. This circulation is maintained by a pump. Into this circulating water the cement is added, and after the mixing has gone on for twelve seconds a valve is opened which allows the grout to be pumped to the drum of the mixer containing the aggregates.

It is claimed that this method of mixing prevents balls of cement remaining unhydrated in the concrete, saves time in mixing, and makes an economical plant lay-out possible because the cement and water can be mixed in the storage shed leaving only the aggregate to be taken direct to the mixer.



Reinforced Concrete Warehouse at Staines. (*See p.* 607.)

Reinforced Concrete Warehouse at Staines.

THE new warehouse which has recently been completed at Staines for the Linoleum Manufacturing Co., Ltd., is a good example of the application of reinforced concrete for a modern industrial building.

A large proportion of the floor area of the warehouse is used for the storage of linoleum. The whole of the building, including the wall panels, is constructed of reinforced concrete. On the ground floor loading and unloading facilities are provided and two 3-ton micro-driven self-levelling lifts are installed, giving access to all floors, in addition to staircases, both for general use and as emergency exits.

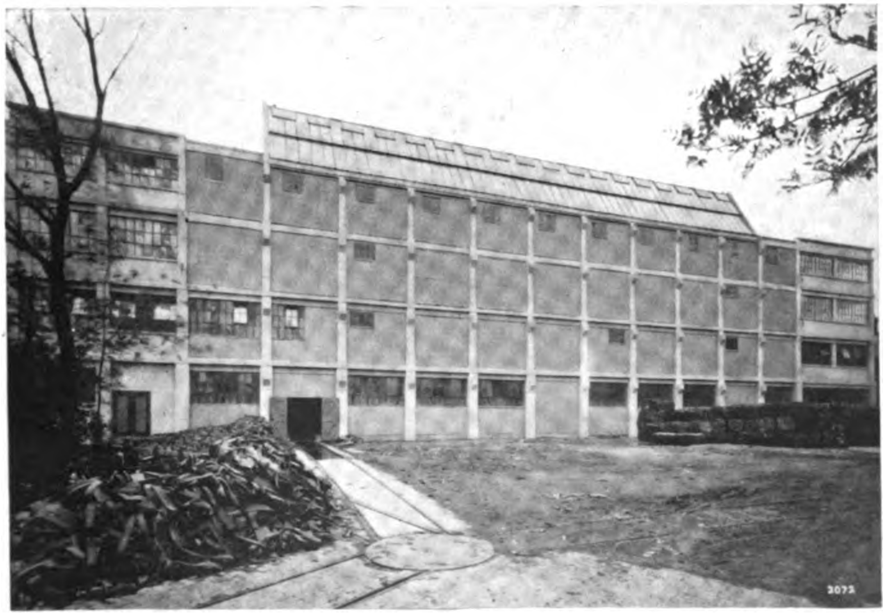
Owing to the somewhat restricted position of the site it has been impossible to obtain a photograph of the front elevation. Our illustrations show the northern elevation, where, as will be seen, provision has been made for the future extension, the window openings being temporarily filled in until this has been carried out at a later date.

The building occupies a site approximately 170 ft. long and 130 ft. wide, and is constructed in four bays each approximately 33 ft. wide, consisting of ground, first, second and third floors and roof.

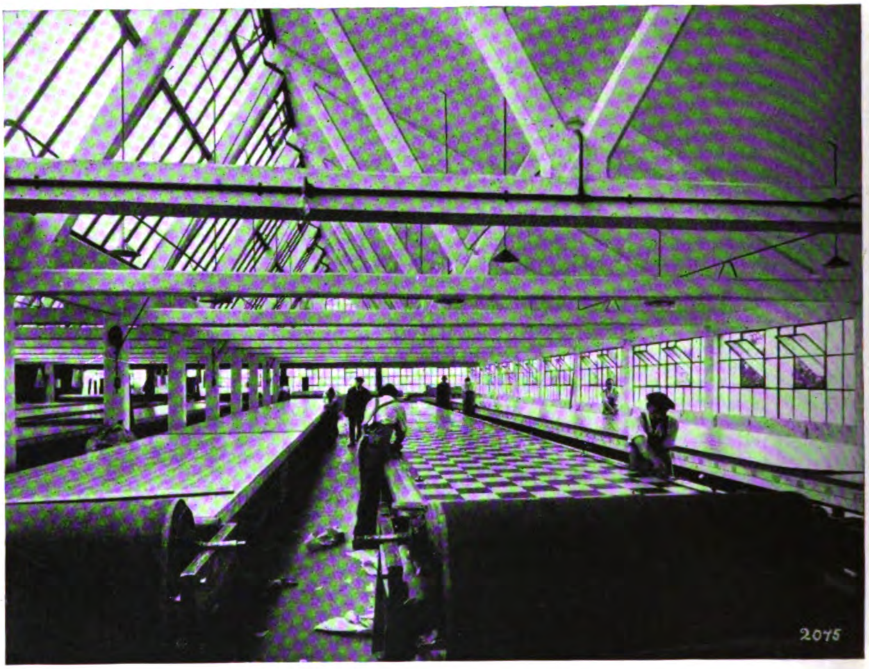
The ground floor is used as a polishing department, the first floor as a warehouse and packing department, the second floor as a warehouse, and the top floor as a trimming and inspection department. The latter constitutes one of the most important departments, as it is here the linoleum is finally inspected before despatch, and it was therefore essential that the maximum amount of natural light should be provided in order that such inspections should be carried out under the best possible conditions. In order to achieve this, not only are large windows provided, but practically the whole of the building is covered with a north light roof.

The total height of the building to the eaves is approximately 45 ft., the ground floor being 13 ft., the first and second floors 11 ft., and the top floor 8 ft.

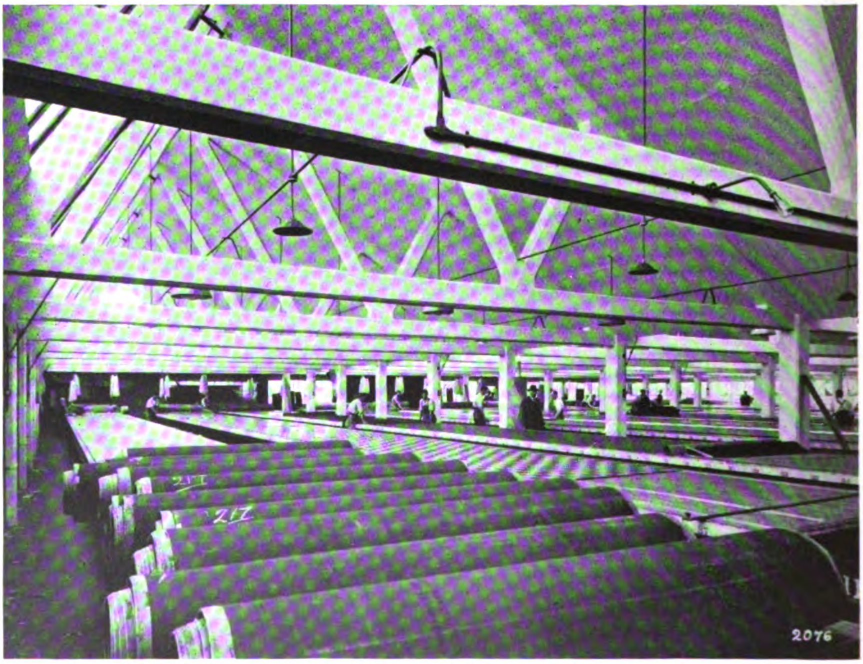
Generally the whole of the floors are designed to carry a super load of 4 cwt. per square foot. An interesting feature of each of the floors is the provision of tramways and turntables which accom-



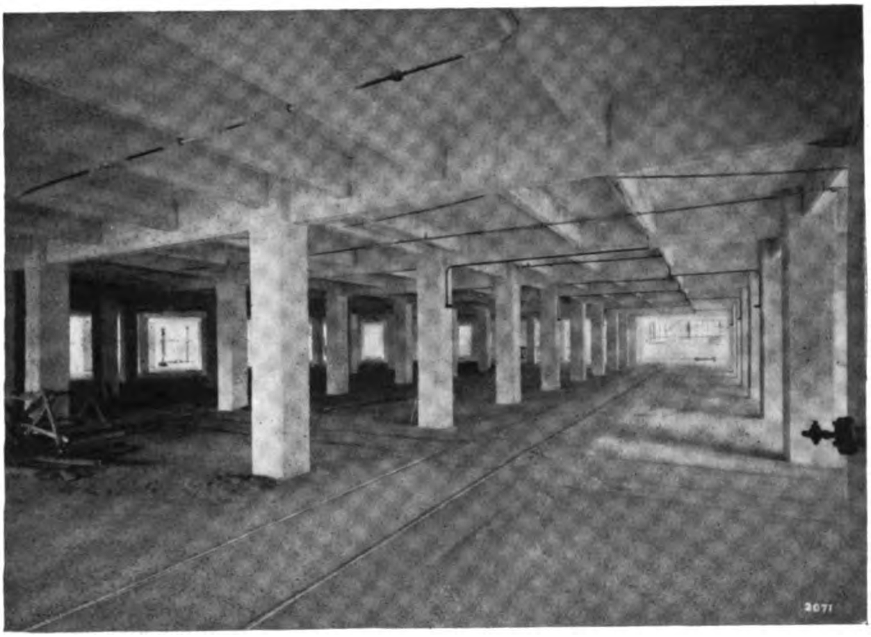
North Elevation.



View under North Light Roof.



View on Third Floor.



View on Second Floor.

modate specially constructed vehicles for conveying the rolls of linoleum, each of which weighs a considerable amount, to various parts of the floors for inspection, storage, etc. The rolls are conveyed to the various floors by the lifts, in the floors of which similar rails are provided, and by means of the turntables which are laid at different points in the floors they can then be conveyed to almost any point.

The foundation of the building rests on ballast and consists of isolated footings, constructed at a depth of 6 ft. below the ground level, which support the columns. The latter, which are square in section, are spaced at 11 ft. 10 in. centres longitudinally, and 16 ft. 6 in. centres in the opposite direction. The size of the columns diminishes at each floor level as the load to be carried is decreased.

The floors are supported on main and secondary beams spanning between the columns and surfaced with granolithic. The lift-wells are enclosed with reinforced concrete walls carried up above the roof level (where the lift house accommodating the machinery is constructed), above which is a reinforced concrete roof slab. The main staircases in the building are also constructed of reinforced concrete.

The north light roof forms an interesting portion of the work, the trusses supporting it, 32 in number, spanning the full width of each bay, a distance of 33 ft., and spaced at 11 ft. 10 in. centres supported at each end on the columns. The face of the trusses accommodating the glazing is 16 ft. 6 in. long, the total length of the double lights being 14 ft. The over-all length of the other sloping side of the trusses is 28 ft. 7 in., slabs spanning between them forming the covering of this side of the roof. Reinforced concrete gable walls at each end, in which a circular light is provided, complete this roof.

The Linoleum Manufacturing Co.'s own engineers were responsible for the whole of the work, which was carried out by Messrs. H. Norris (Builders), Ltd. The reinforced concrete work was carried out in accordance with the design and specification of the Indented Bar and Concrete Engineering Co., Ltd.

Bond between Steel and Concrete.

In a paper read recently before the Western Society of Engineers, Mr. T. D. Mylrea, Assistant Professor of Structural Engineering at the University of Illinois, said :

In a beam containing a definite amount of reinforcement, straight and full length, the position of the neutral axis remains fixed at a position somewhat below mid-depth until cracking occurs. Moreover, before cracking the bond is probably perfect, and the steel therefore takes a constant proportion of the total tensile stress at all points along the beam. This proportion is about 45 per cent. for beams with percentages of steel of from about ½ per cent. to 2 per cent. In such cases the steel stress varies directly with the ordinate to moment diagram, although accounting for only part of the total tension. If the value of *V* in the bond formula is reduced in the same proportion, the formula will give the correct distribution of bond in the beam before cracking.

When a beam is loaded heavily enough to produce design stresses in steel and concrete, it is cracked throughout a considerable portion of its length ; and cracks greatly modify this distribution of bond. Wherever the concrete in a beam has cracked, the steel stress is at least as high as its computed value, neglecting the tension taken by the concrete between the top of any crack and the neutral axis, which rarely amounts to more than a very small percentage of the total tension. Between cracks the steel tension varies considerably, of course, from a maximum at the crack to a value that at early loads may be less than half that amount approximately midway between cracks. At high loads the stress midway between cracks approaches the computed value, and then the steel stress at cracks away from the point of maximum moment may actually be higher than computed, due to the failure of bond between cracks.

In a simple beam, the magnitude of the stress at the crack nearest the support, and hence the load carried, may be limited in certain cases by the tension that can be developed in the steel by bond between that crack and the end of the bar.

Tests indicate that the actual average bond stress developed in a simple beam at first end slip, but not the nominal value determined by the bond formula, including the overhang, is in the neighbourhood of 200 lbs. per sq. in. on round bars in 1:2:4 concrete about eight months old. The usual specified limit of 80 lbs. for such bars thus represents a factor of safety of about 2½ in concrete of this description. But we are not at all certain of the stress at the last crack, which may be higher than computed. Thus we are in the uncomfortable position of knowing that the bond formula does not give the true bond and yet having no means of finding out what the true bond is. There is some comfort in the thought that the bond value determined by the usual formula from test beams failing in bond, with a suitable factor of safety applied, will give the same factor of safety when used in designing similar beams by the same formula, even though the actual bond stress is not known in either case. It should be borne in mind, however, that we are then dealing solely with factors of safety, in spite of the familiar assumption that designs are based on working stresses rather than on ultimate strengths ; and there is no valid reason for assuming that such values will be obtained in beams varying very widely in shape from the test beams.

Since failure by diagonal tension occurred in the beams with large overhang, it seems reasonable to suppose that the slip over the support was more than at the end, and that a tension of some magnitude existed there. Therefore, the movement of the bar just inside the support would be larger at the beginning of end slip than where end slip was first noted in the beams without overhang. This would allow the end cracks to widen, with the resulting diagonal tension failure. Thus, slip of bar may not only result in bond failure, but may be the primary cause of other forms of failure.

It appears that the maximum bond stress developed, as computed from the maximum load carried by a short time specimen, is unsafe as a basis for determining working stresses, since the first end slip marks the beginning of the end.

If the reinforcement in a beam consists of several parallel bars, and if for economy some are cut off where no longer needed to resist moment, serious disturbances in bond stress may be expected. The cut-off bars must develop a steel stress varying from zero to a maximum in the same distance that a much smaller difference of stress is developed in bars not cut off. Hooking the ends of the stopped off bar will not help the condition unless proper precautions are taken, since hooks tend to concentrate stresses in a region which is already in tension, thus inviting cracks, with a marked tendency to split the beam.

In beams where bars are bent up at an angle to resist shear, conditions are more favourable, especially if the bends are of long radius. If the bends are sharp, they have practically the same effect as hooks. For uniform bond strength in continuous beams with a single concentrated load in the middle of each panel, the distance from the column to the points where bars are bent down should be the same as the distance from the midspan of the beam to the points of bending up of bars. The length of bar in bond thus being the same for the same stress, the down bends will be called upon to furnish the same degree of anchorage as the up bends.

It is common to see designs in which the bars resisting negative moment are bent down close to the support for the purpose of resisting shear. While this may be quite permissible for the moment diagram, it is usually bad practice from the standpoint of bond, since the bend must furnish full anchorage and may split the beam.

While the anchorage of bars is an important consideration, which may be effected with varying success in different ways, perhaps the simplest method is to extend the bar far enough to develop it by bond.

Mechanical anchorages of various kinds have often been used when the bond was deficient. Nuts and washers on the ends of bars are reported to have been tried years ago by Thaddeus Hyatt, with unsatisfactory results. In another series of tests, a rather unique anchorage consisted of a plate with holes in it applied to each end of the beam, the reinforcement projecting through the holes and being bent back against the plate. It seems probable that the diagonal tension failure which always followed was due to slight end slip which this type of anchorage did not prevent. Tests of bars anchored in cylinder by means of nuts and washers show that "enormous pressure may be transmitted by concrete under these anchorages." None of the specimens was reinforced to prevent bursting, and in all cases failure was by splitting of the concrete blocks. The conclusion is that "the use of washers or bearing plates of ample area and stiffness which are rigidly attached to the reinforcing bar will accomplish much in increasing the usefulness of this form of anchorage."

The right angle bend has always been a favourite form of anchorage in the United States. In Germany the bend of 135 deg. is common; in France and England, the "fishtail" bend originated by Hennebique has been popular. Considère introduced the curved hook. Present practice in all these countries is becoming strongly in favour of this hook, usually with an opening larger than the 5-diameter clear opening recommended by Considère. The Joint Committee in its report of 1924, recommends a hook whose diameter is 8 diameters centre to centre.

It is noteworthy that in all the types of mechanical anchorage mentioned, failure occurred by splitting of the specimen. When washers were used, their flexure was undoubtedly responsible; and for maximum efficiency they should be very rigid, or reinforcement against bursting should be provided. Fishtails are liable to be flexible, while all forms of hooks and bends exert a severe splitting force because of their shape. The tendency of round bars to split the concrete evidently has a marked influence on the value of bends and hooks. This tendency is more severe where the mass of concrete to be split is small. If it is desired to reinforce against bursting by means of a spiral around the hook, the stress in the spiral must be kept low enough to prevent incipient splitting, say not over 5,000 lbs. per square inch.

Conclusions.

The following summary gives some of the more important points brought out in this discussion:

(1) Bond is induced only by a difference in stress at two points in a reinforcing bar.

(2) Before a beam cracks the actual bond is everywhere much less than the computed bond.

(3) After a beam cracks the actual bond may be much higher than the computed bond, even in the uncracked region.

(4) First end slip of a bar measures the ultimate long-time load capacity of a simple beam.

(5) The ordinary bond formula is unreliable in beams in which bars are cut off.

(6) The bond formula is unreliable for negative reinforcing of continuous beams.

(7) The bond formula is erroneous for beams in which the reinforcement is inclined with reference to the compression face.

(8) In such beams anchorage is essential.

(9) The extension of a bar may serve to anchor it.

(10) Nuts and washers, properly spiralled, should make good anchors.

(11) Bent or hooked bars tend to split the concrete.

(12) Right-angle bends exert severe concentrated pressures and splitting stresses on concrete, and are liable to break off if the steel is brittle.

(13) Where the mass of concrete to be split is small, as in the web of a beam, it is unwise to increase allowable bond on bars simply because they are hooked. Destructive secondary effect may follow.

(14) Semi-circular hooks should not be of too large opening.

(15) The splitting tendency of semicircular hooks may be easily reinforced against, and such hooks may form good anchorage.

Book Reviews.

"The Lightning Graphs." Series 1 (General). By I. S. Dalgleish, A.M.I.E.E.

(Size 9¾ in. × 7¼ in. 12 pages, 10 plates.) London: Crosby Lockwood & Son. Price 5*s*. net.

THE great utility of alignment charts in evaluating mathematical formulæ deserves to be more fully recognised. In structural engineering the data available are often only rough approximations, so that meticulous accuracy in the application of formulæ is not warranted and a slide-rule usually gives results with a considerably less percentage error than the probable error in the assumed loads dealt with, or any of the other assumptions made.

An alignment chart is often equivalent to a slide-rule or combination of slide-rules set in a certain position so that if the values of two of three related quantities are known, by laying a straight-edge on points on two scales corresponding to these known values, the value of the third can be read on a third scale at the point where the straight-edge crosses it.

The ingenious charts in the book under review (whose title indicates the speed with which results can be obtained by the graphs, and not their connection with electrical engineering) are not of great utility to the structural engineer. They give the value of the unknown variable in $a^2 = b^2 + c^2$, $a^n = d$, $\sqrt{a} = d$, and also hyperbolic logarithms and reciprocals.

For obtaining the length of the side of a right-angle triangle by means of the first equation, however, a 10-in. slide rule is often not sufficiently accurate and reference has to be made to logarithmic tables.

To the maker of an alignment chart the application at the time of making is obvious, but experience has taught the reviewer that it is advisable to indicate by an example exactly how the chart should be used and he hopes this suggestion will be acted on in the further charts promised by the author.

The graphs are very neatly made and well reproduced. They afford an excellent opportunity to the inquiring mind, to find out how they have been constructed, of which the text gives no hint.
—W. A. G.

"Coal and Ash Handling Plant." By John D. Troup, M.I.Mech.E.

London: Chapman & Hall, Ltd. Price 13*s*. 6*d*. net.

THE various methods of mechanical handling of coal and ash in industrial plants are comprehensively dealt with in this volume. Of particular interest to those concerned with these problems are the illustrations and descriptions of typical modern designs and lay-outs for the purpose. We note that attention is called to the possibilities of making bricks from waste material, such as clinker and ash, from power stations, and the author advocates that large fuel consuming undertakings should set up special departments for their manufacture. The subject of reinforced concrete coal bunkers is very briefly touched upon.

The Brigitta Bridge, Vienna.

By R. N. STROYER, M.I.Mech.E.

SOME time ago competitive tenders and designs were invited for a bridge over the Donankanal, a branch of the Danube, in Vienna, and as the result of the tendering brought out to a marked degree the superiority of reinforced concrete as compared with steel structures, it may not be without interest to give a short review of the various designs submitted, although the final decision of the Vienna Office of Works resulted in a steel structure being preferred, for reasons other than technical.

The old Brigitta bridge, like all the other bridges over the Donankanal, was a steel structure, the life of which on an average amounts to about fifty years, and was due for reconstruction before the war, when competitive designs in steel only were invited. As a result of strong protests by leading concrete engineers, principally Dr. Emperger, the renewed invitation for tenders and designs last year allowed the inclusion of reinforced concrete designs, but the general conditions and specification prescribed for the work were such as to favour unduly the steel structures officially preferred. A slight idea of the difficulties introduced by the insistence on trifling details is given by *Fig.* 1, where the prescribed towing path under the bridge and the traffic opening next to it are shown in full lines. As will be seen, the thrust from an arch does not pass straight into the abutment proper and therefore requires special means for transferring to the latter, whereas a lowering of the tow-path and a lifting of the traffic opening by a few inches, as shown in dotted lines, would have eased the construction immensely. A steel girder with vertical loads only, such as contemplated by the official mind, would of

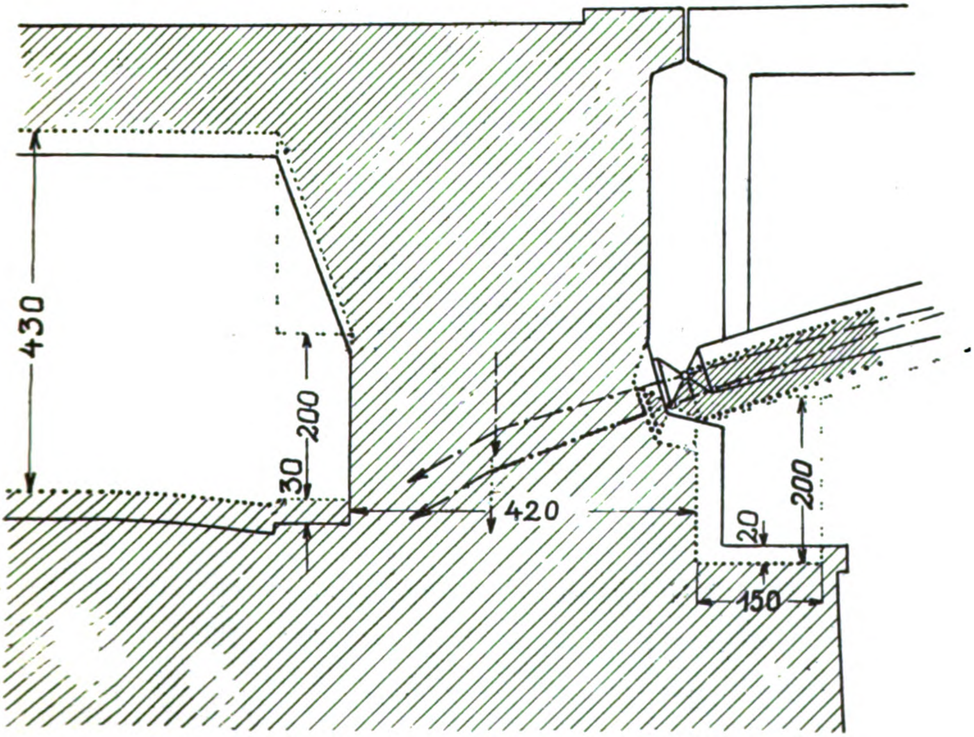
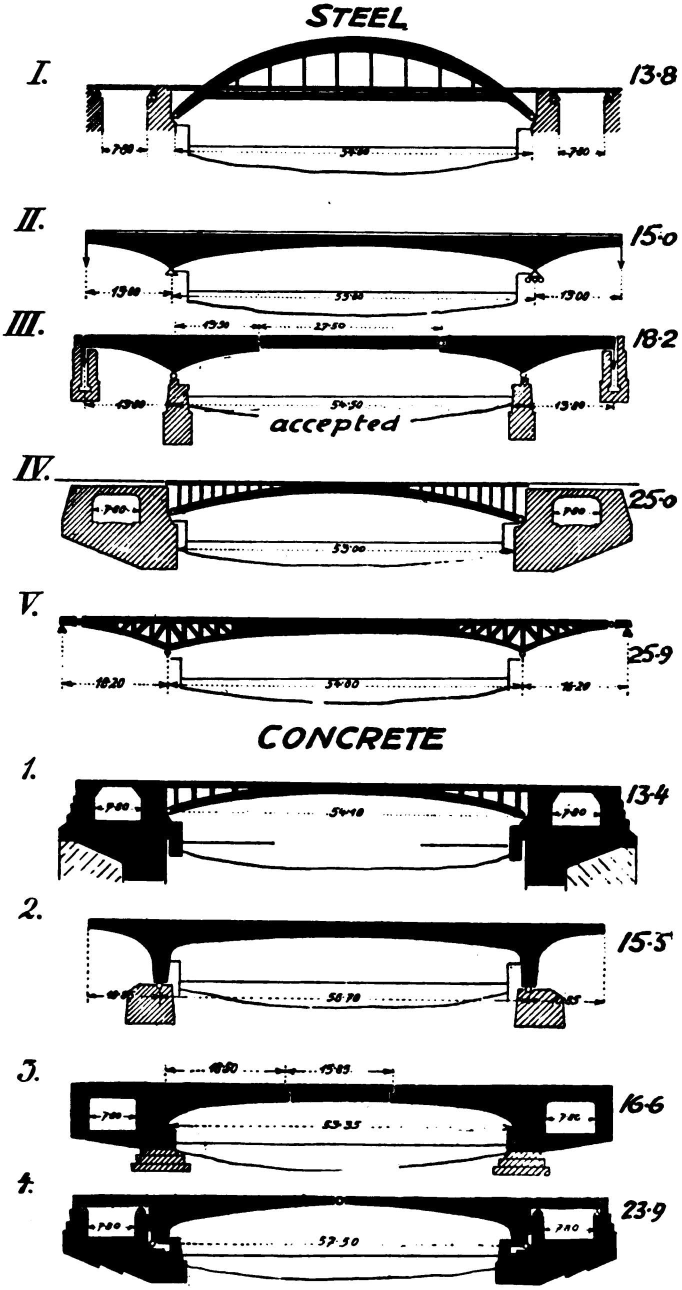


Fig. 1.


STEEL
I.
13·8
7·80
54·50
7·80
II.
15·0
13·00
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13·00
III.
13·50
27·50
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13·00
54·50
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IV.
7·80
7·80
25·0
55·00
V.
25·9
18·20
54·00
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CONCRETE
1.
13·4
7·80
54·10
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2.
15·5
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56·70
10·85
3.
18·50
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16·6
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53·35
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4.
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7·80
57·50
7·80

Fig. 2.

course not be inconvenienced by this point.

The result of the tendering is shown diagrammatically in *Fig.* 2, where five steel designs and four reinforced concrete designs are tabulated in order of cost, the figures denoting milliards of Austrian crowns (at their then value). The schemes all have a clear midspan of about 165 ft. (50 m.) with two towing paths of 5 ft. each, and two endspans of 25 ft. each for riverside traffic. A more detailed comparison of the costs of the various schemes is given in Table I, in which the cost of the foundation is separated from that of the superstructure.

The schemes in the table are arranged according to their form of design, and a glance will show that for any particular type of construction the reinforced concrete scheme is the cheaper in the first instance, apart from considerations other than capital outlay. This is another proof of the competitive ability of reinforced concrete when compared with other forms of construction, and if the tendering has done nothing else than show this the result is still gratifying to the concrete engineer.

The cheapest superstructure appears to be a steel arch with underhung roadway (I), but as this form of construction was not likely to be approved on architectural grounds no reinforced design of this type was submitted. The next steel scheme (II) was rejected by the authorities on technical grounds, and for a decision prejudiced in favour of a steel structure this left practically only scheme (III) for consideration, as the remaining two were too expensive,—hence the former (III) was recommended for acceptance.

As the comparison between reinforced concrete and steel is instructive, so might a comparison between the four concrete designs be useful, and it will be instrumental in showing the advantage of the special form of hooped cast-iron reinforcement introduced by Dr. Emperger. In the following short description of the four reinforced concrete schemes the order will be reversed, starting with No. 4.

TABLE I

(Cost in milliards of Austrian crowns.)

Type of Construction.	Reinforced Concrete Schemes.				Steel Schemes.			
	Scheme No.	Foundation.	Superstructure.	Total.	Scheme No.	Foundation.	Superstructure.	Total.
Two-hinged arch, roadway below	—	—	—	—	I	7·46	6·36	13·82
Two-hinged arch, roadway over	1	6·91	6·48	13·39	IV	3·41	14·59	18·00
Continuous girder . .	—	—	—	—	II	5·15	9·89	15·04
Two-hinged rigid frame	2	8·73	6·73	15·46	V	(11·88)	13·89	25·86
Cantilever	3	6·95	9·61	16·56	III	(9·01)	9·21	18·22
Three-hinged rigid frame	4	7·22	16·65	23·87	—	—	—	—

(The bracketed figures are for caisson foundations.)

Scheme No. 4—Three-Hinged Frame.

In recognition of the disadvantages of an ordinary arch, on account of the small rise obtainable by the tow-path conditions, the three-hinged frame has been chosen as the most suitable construction, the bottom hinges being placed at a low level so that the thrust from the arch-frame is not only decreased in magnitude, but also enabled to pass straight into the foundation-block instead of being transmitted through the vertical abutment wall, as in the case of the arch. The formation of the arch-frame and the construction of the foundations are seen from *Figs.* 3 and 4, the latter being somewhat heavier than necessary for the spreading of the load in order to allow the weight to deflect the thrust from the superstructure. This latter is divided into four separate units, as the bridge itself is slightly skew. The hinges are formed as steel castings.

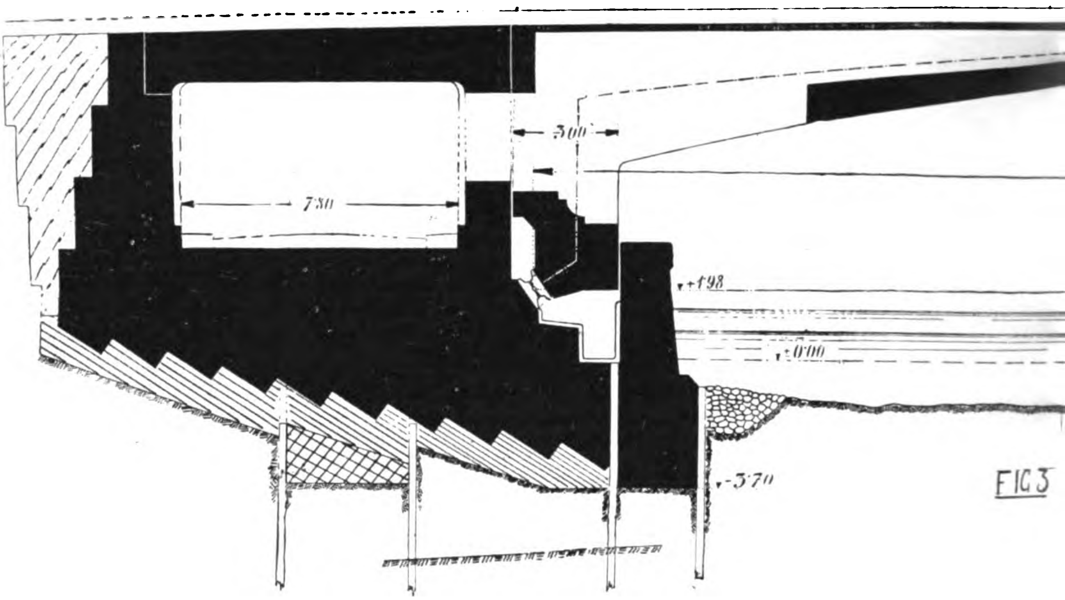


FIG 3

Scheme No. 3—Cantilever.

For the same reasons as mentioned in the previous scheme an arch construction has been avoided, and cantilever arms from the abutments carry a freely-supported mid-span girder of about 50 ft. length resting on steel rollers between steel plates. In order to provide a sufficiently heavy and immovable abutment for the fixing of the cantilevers the whole of the small end-span has been embodied in the abutment block. A longitudinal section of the structure is shown in *Fig.* 5, while *Fig.* 6 gives a cross-section showing details of reinforcement in the freely-supported middle girder. The superstructure is carried by six ribs, of which two are under the footpaths while the remaining four carry the roadway. The main ribs are continued across the end opening, and the space between them at this point is filled with mass concrete to increase the counterweight effect from the end span. A feature of this particular design is the advantage, during construction, of keeping the middle 50 ft. clear for canal traffic, as only the two cantilever arms are built on piled temporary staging, while the centering for the mid-span is suspended by trusses from the finished cantilevers.

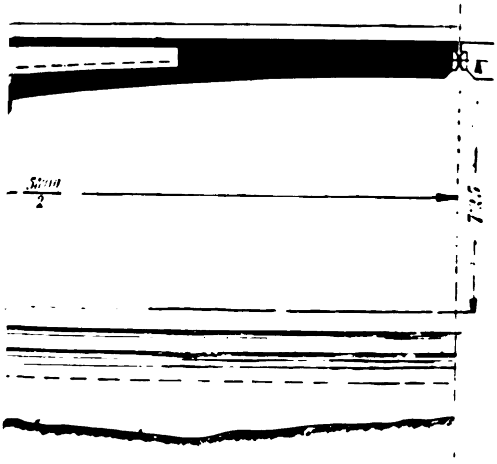
Scheme No. 2—Two-Hinged Frame.

The superstructure is a rigid frame with hinges at the foot and two overhanging ends, the rise from the hinges to the middle being about one-tenth of the span. *Fig.* 7 shows a longitudinal section of the bridge, and *Fig.* 8 gives some details of the cross-section at mid-span. The superstructure is split up into ten ribs, of which four carry tramway rails directly, and which are continued into the cantilever end-spans, at which point the space between them is filled with mass concrete. Between the ribs in the main span, cross-beams are provided to distribute the loads from the bridge.

The hinges are formed in the concrete itself by ensuring a zero point for moments at this particular point, where the reinforcement is brought to the neutral axis of the section—a form of hinge that has been described by the writer in an earlier issue of this journal.

Scheme No. 1—Two-hinged Arch (Hooped Cast Iron).

On account of the relative levels of the tow-path and the end opening there is considerable difficulty, as mentioned above, in constructing an arch with a satisfactory rise if ordinary reinforced concrete is used, as the dimensions



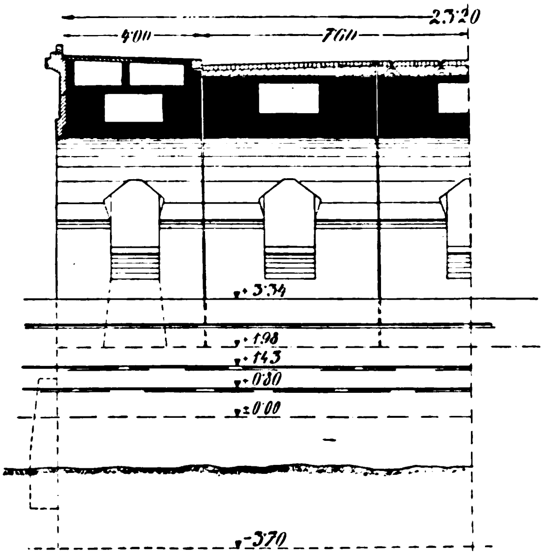


FIG. 4

required would make the arch too flat, with a rise of about 1 in 16. By the use of a high-compressive material, such as hooped cast-iron, it is, however, possible not only to improve the rise to 1 in 14 by the slimness of the arch ring, but to keep the shape of the arch so that the stress line everywhere is within the middle third of the section; in other words, no tension whatever is produced by any loading. By allowing tension in the section it would be possible to increase the slimness still further and obtain a still better rise, but in order to avoid anything which might give the authorities an opportunity to reject the scheme this expedient was not suggested, although a great number of satisfactory tests have been carried out by Dr. Emperger on sections subject to eccentric loading and in which the tension side was reinforced with mild steel and the compression side with hooped cast-iron. The mild steel bars introduced in the arch ribs of the bridge in question are therefore not strictly needed. The longitudinal section of this scheme is shown in *Fig.* 9, while *Fig.* 10 shows a cross-section.

The Austrian regulations for reinforced concrete recognise that inventions and improvements may be brought forward in the course of time, and provide for the testing of novel constructions such as are not contained within the compass of the regulations, requiring a factor of safety of at least 3 to be shown by the actual testing of a member identical with the one proposed. As the system of hooped cast-iron does not come within the cases provided for in the regulations, a test was requested to be carried out on a member corresponding to the crown section of the arch rib, which statical calculations had shown to be subject to a maximum thrust of 411 tons with an eccentricity of 16·6 cm.

In order to enable a test to destruction to be carried out in the 1000-ton machine at disposal at the engineering college, it was decided to employ a half-size section only, made from weaker materials than those proposed for the actual structure. The concrete used for the test piece gave a crushing strength of 1700 lbs. and 2000 lbs. per sq. in. after 10 and 20 days respectively and the cast-iron 98,000 lbs. per sq. in., so that in comparison with the guaranteed 3000 lbs. and 128,000 lbs. per sq. in. for the concrete and cast-iron to be used in the bridge the material strength of the test piece was only 74 per cent. This, in combination with the half-size dimensions gave, instead of the 411 tons on the actual structure,

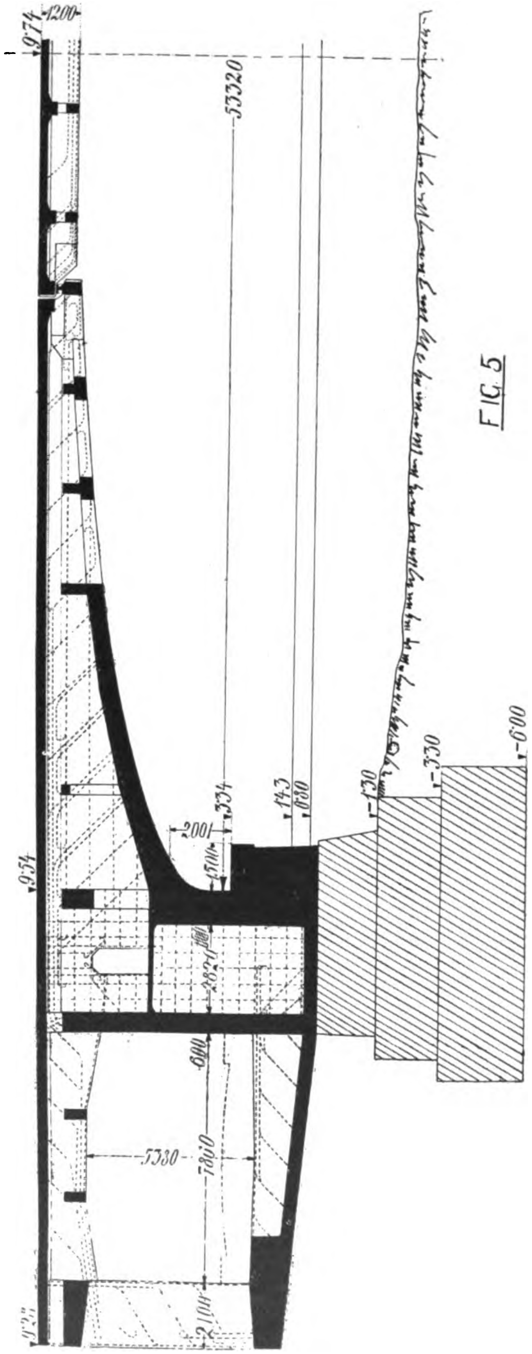

9.74
1200
53320
9.54
2001
334
1500
143
080
130
330
600
2821
800
5330
7860
2104
9.28

FIG. 5

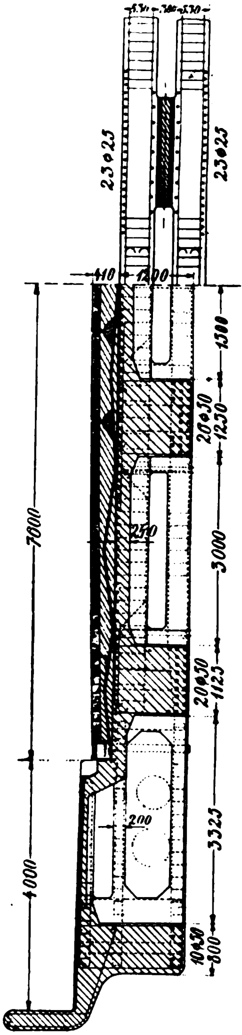

23ø25
23ø25
20ø50
20ø50
10ø50

FIG. 6

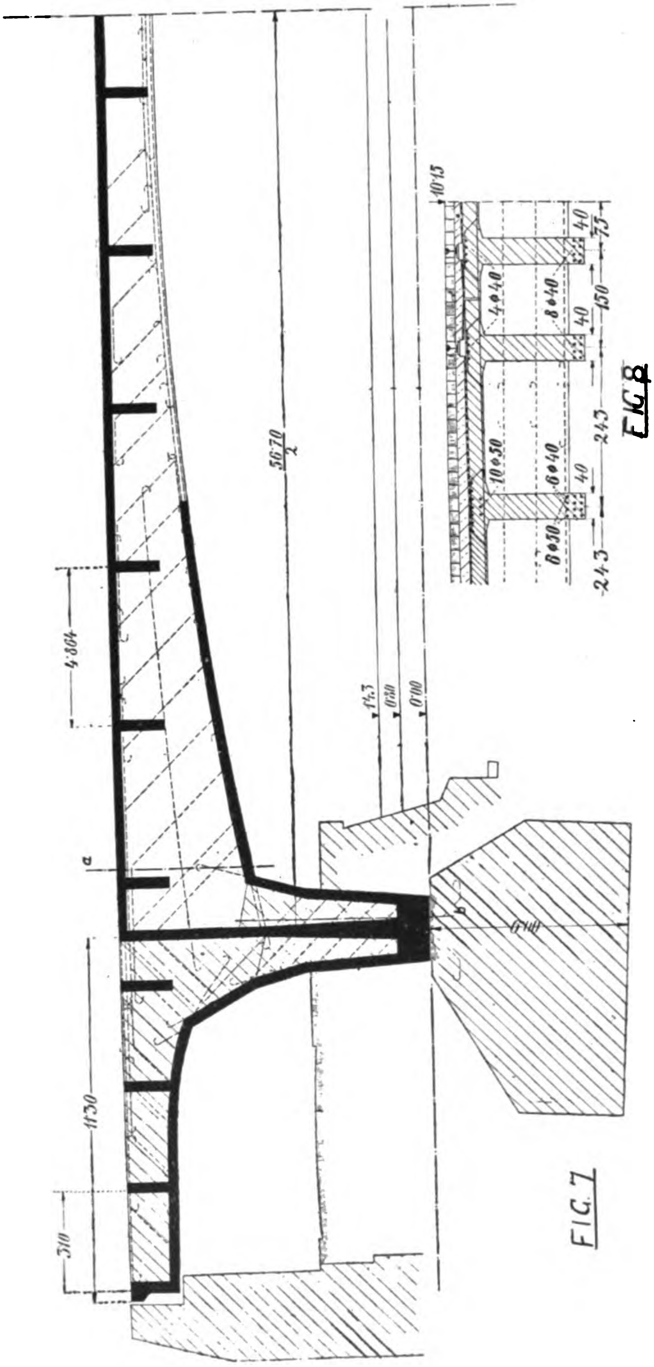

56·70/2
4·864
a
1130
310
14·3
0·80
0·00
b
6·00
10·15
40
75
150
4ø40
8ø40
40
243
10ø50
6ø40
40
8ø50
243

FIG. 8

FIG. 7

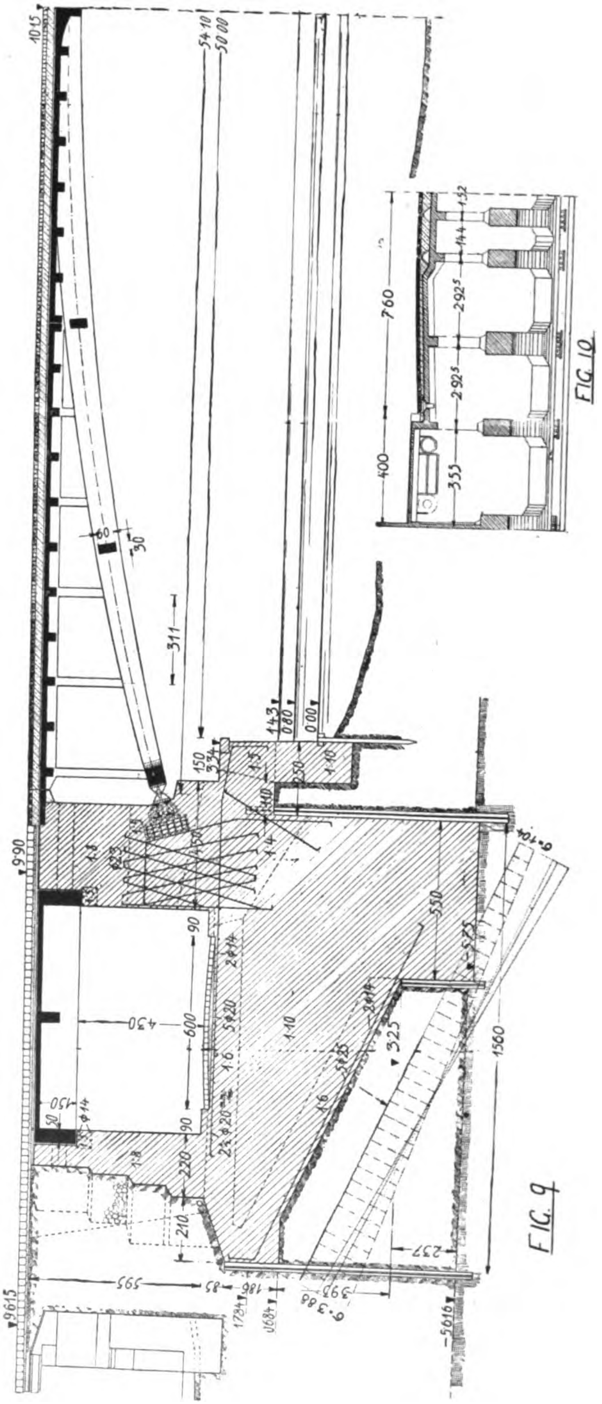

10·15
54·10
50·00
60
30
311
1·43
0·80
0·00
150
3·74
1·5
2·50
1·10
3·40
9·90
1:4
1:8
550
5·25
9·10
1500
3·25
2Ø14
5Ø20
1:10
1:6
430
600
90
220
210
595
85
186
1·784
1·4890
3·98
9·388
2·37
9·615
5·616
150
50
Ø14
760
400
355
2·925
1·44
1·52

FIG. 9

FIG. 10

a calculated load on the test piece of 411 × 0·74 × 0·5 = 160 tons at an eccentricity of 11·7 cm. The dimensions of the test piece are shown in *Fig.* 11.

The test was carried out while the concrete was still green, and at a load of 650 tons, more than four times the safe load, the hooping gave way under the lateral expansion of the concrete, but on chipping away the latter the cast-iron was found to be absolutely sound (*Fig.* 12). The amount of hooping had been purposely chosen too low so as to allow the concrete to give way first, in order to show the cast-iron being intact at that moment, but by increasing the volume of the hooping to the same amount as in the bridge design it would have been easy enough to obtain a factor of safety of 5. This relatively high factor of safety in the design was adopted with a view to the future development of the traffic and consequently the life of the bridge, and in this connection it is interesting to compare the arch scheme with the steel bridge chosen by the authorities.

The total live load on the bridge is 763 tons and the dead load of the proposed arch bridge is 2260 tons, against 830 tons of the steel bridge; Table II gives a vivid comparison between the

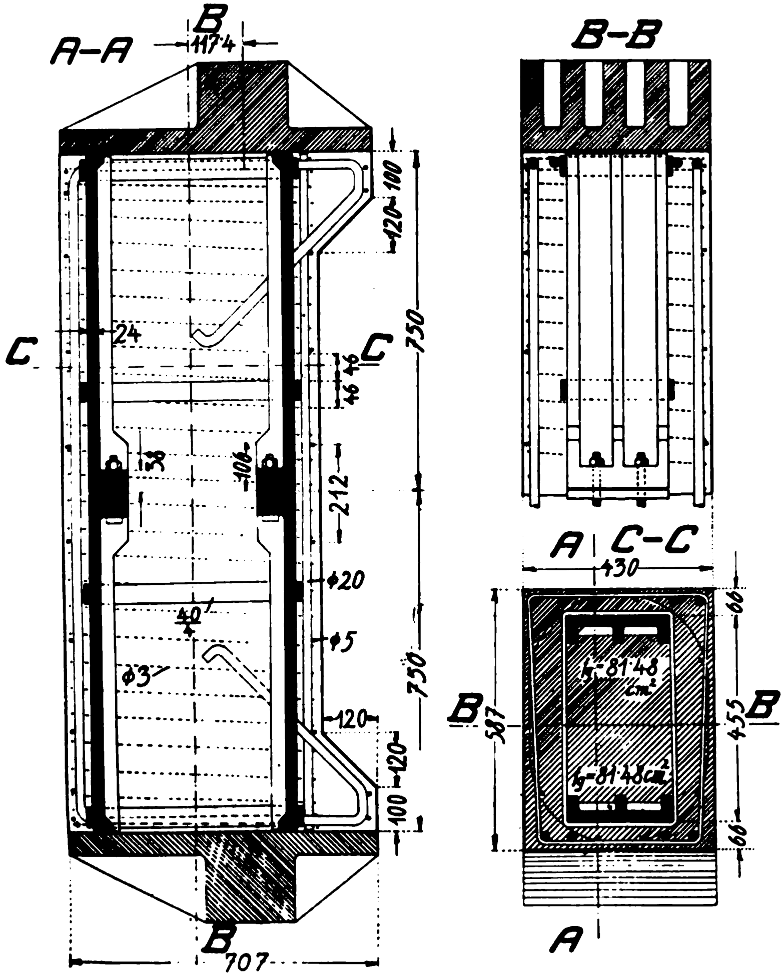


Fig. 11.

two schemes in regard to an ultimate increase in traffic of 50 per cent., by no means improbable in a few years' time.

TABLE II

	Reinforced concrete design.	Steel design.
	Tons.	Tons.
Super Load .	763 (25%)	763 (50%)
Dead Load .	2260 (75%)	830 (50%)
Present Total .	3023 (100%)	1600 (100%)
50% Super Load	382 (13%)	382 (24%)
Future Total .	3405 (113%)	1982 (124%)

While, in these circumstances, a concrete bridge may easily stand the increase of 13 per cent. simply on account of the time increase in strength of the concrete, and therefore practically without any decrease of the factor of safety of 5, an increase, on the other hand, of 24 per cent. in a steel structure becomes a serious matter in view of the usual factor of safety of 2½ to 3, and would mean reconstruction. It is obvious that, viewed from this angle, the steel structure, to be of equal value from an economic point of view, should have a factor of safety essentially higher than 5, all the more so as the proportion of impact load

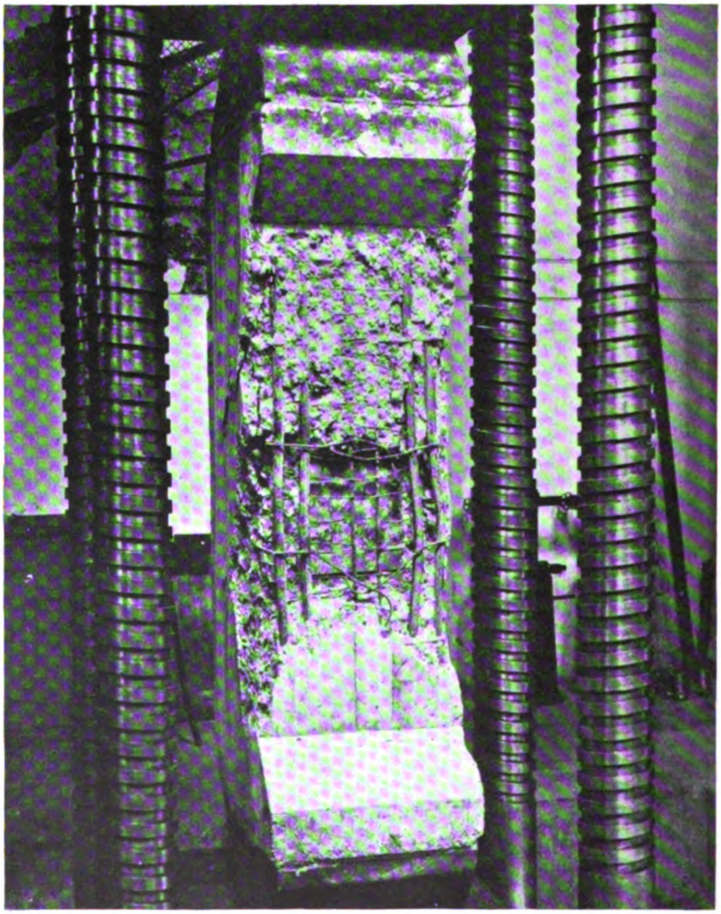


Fig. 12.

to the dead load in the steel structure is 1 to 1, but in the concrete structure 1 to 3.

It therefore seems no exaggeration to say that in view of these considerations the steel bridge appears very much in the nature of a temporary structure as compared with the concrete bridge with twice the factor of safety and the true stamp of permanency.

Table III enables a comparison to be made of the quantities required for the four concrete schemes, and it will be seen that the hooped cast-iron system is by far the most economical, a contributory factor to the cheapness of the tender being the quickness with which the centering can be struck immediately after the concrete has been poured and has set.

TABLE III

Scheme.	Material.	Quantities in Superstructure.	Quantities in Foundations.
No. 1	Concrete	1350 cu. yds.	6900 cu. yds.
	Steel Bars	148 tons	65 tons
	Cast Iron	80 tons	
	Cast Steel	17 tons	
No. 2	Concrete	3920 cu. yds.	4650 cu. yds.
	Steel Bars	406 tons	or Caisson
No. 3	Concrete	4650 cu. yds.	4130 cu. yds.
	Steel Bars	749 tons	
	Cast Steel	20 tons	
No. 4	Concrete	4565 cu. yds.	3950 cu. yds.
	Steel Bars	1005 tons	396 tons
	Cast Steel	88 tons	
No. III	Sectional Steel	830 tons	Caisson

Adhesion between Steel and Plaster-of-Paris.

ALTHOUGH there is in existence a considerable volume of research results on the bond between steel and concrete, the important question of adhesion between steel and plaster appears to have been neglected until quite recently. At the request of the Union Technique du Bâtiment et des Travaux Publics, M. Anstett carried out some research work on this latter question. The results were communicated to the Franco-Belgian Association for Testing Materials and reported in *Revue des Materiaux de Construction*, to which review we are indebted for the following summary.

Mild steel bars, ⅝ in. in diameter, were fixed in cubical moulds with 4-in. sides which were filled with plaster gauged with 50 per cent. of water. After a period of 48 hours the moulds were stripped and the cubes were kept either (*a*) in an oven at 30° C. to secure complete drying of the plaster, or (*b*) in damp air at 15° C. Seven days after gauging tests were made of the stress required to pull the bars from the plaster.

The test bars had undergone the following treatments before being cast in the plaster:

(*a*) Carefully cleaned with fine emery paper;

(*b*) Completely rusted by prolonged exposure to water;

(*c*) Coated the previous evening with red lead oxide;

(*d*) Coated several days before with a layer of red oxide so as to be completely dry when cast in the plaster;

(*e*) Rendered with cement grout which was perfectly dry when cast in the plaster.

The following average results were obtained for the tangential adhesion after seven days' hardening.

Treatment of bar.	Plaster oven dried. lbs. per sq. in.	Plaster kept air damp. lbs. per sq.in.
(A)	90	51
(B)	256	135
(C)	59	37
(D)	122	71
(E)	129	13·5

Summary of Conclusions.—Rendering the bars with cement grout only gives good results if the plaster is kept perfectly dry.

The highest adhesion is obtained with rusty bars.

Perfectly dry oxide coating adheres better than bare steel.

The adhesion of bars in damp plaster is only about one-half of that where the plaster is dry, except where the bars are coated with cement grout, in which case the ratio is only about one-tenth.—W. S. G.

Questions and Answers Relating to Concrete.

Design of a Water Tank.

QUESTION.—In the design of a reinforced concrete water tank 150 ft. square with 18 ft. of water, is it necessary to make provisions for temperature changes? If so, where is the correct place to insert expansion joints, and what is the best form of an expansion joint?

(2) Also, what would be the best method of construction: to finish off to the proper height one wall at a time, or concrete all around in equal lifts, assuming that patent shuttering is used?

(3) Suppose a long crack appeared in a ferro-concrete wall due to temperature changes, what would be the best method to adopt to render the wall water-tight? H. D. NEEP.

REPLY.—(1) A reinforced concrete tank 150 ft. square, if standing above the ground, would certainly require expansion joints. If completely embedded and covered with earth over the roof the changes of temperature might be so small as not to require expansion joints. There are various forms of expansion joint: one consisting of bent copper sheet projecting into both sides of the reinforced concrete and capable of a "concertina action"; another depends on the use of asphalte or similar plastic substance.

(2) It is generally best to bring the concrete up uniformly. Great care must be taken at the construction joints. New concrete should be bedded on a layer of soft cement mortar at the construction joints to prevent honeycombing and leakage at these places.

(3) This depends entirely on the nature of the crack. If it is one which opens and closes with change of temperature (which temperature cracks generally do) then an elastic joint such as that described above is the only one which will stand, otherwise cutting out the crack by a chase and filling up with cement mortar 1 to 1 is generally effective.—O. F.

Loam in Sand.

QUESTION.—I shall be obliged if you will let me know what percentage of loam is permissible in sand used for concrete in general reinforced concrete work without having a detrimental effect on the resulting concrete. The Standard Specification recently published in your pages states: "Sand . . . free from . . . loam or other deleterious substances." Would the presence of loam to the extent of 10 per cent. or 12 per cent. be positively harmful?—A. N.

ANSWER.—The percentage of loam permissible in sand depends entirely on the nature of the loam. Some loams consist of small particles of grit too fine to be considered as sand, whereas in some cases the loam consists of fine particles of clay, and the presence of a clay loam is, of course, considerably more harmful than when the loam is very fine grit. As a general rule it is advisable to consider 5 per cent. loam in the sand to be the absolute limit.

In cases of doubt the best way to decide upon a particular sample of sand would be to wash thoroughly a portion of the sand to rid it entirely of loam, and with this washed material make a number of briquettes with cement, a similar number of briquettes being made with the sand unwashed and the same cement. These should be tested, and the results compared with each other and with a series of briquettes made with standard sand and the same cement.

The "Portland House" Scholarship.

The Institution of Structural Engineers has awarded the Portland House Scholarship (£300 and gold medal) to Mr. George Robertson, who is at present employed as Assistant Engineer to the City Engineer of Bath. Under the terms of the Scholarship award he will be required to travel on the Continent and in America to study modern concrete development. The Scholarship consisted in a preliminary written examination in structural engineering followed by a final competition in design, the subject this year being a large reinforced concrete bridge. The Institution awarded a silver medal to Mr. C. J. Wood of Purley, and a bronze medal to Mr. F. W. Davey of Victoria Street, S.W., the two candidates placed next in order of merit.

Uniform Rolling Loads on Rigid Arched Ribs.

By G. S. COLEMAN, D.Sc.(Eng.), A.M.Inst.C.E.

THE use of influence line diagrams has greatly facilitated the calculation of the various forces and bending moments in connection with rigid arch ribs. Handbooks of constructional engineering, however, usually only give references to the action of single rolling loads, whereas the commoner case is that of a uniform load extending over a portion of the span. In such a case it will be necessary to find the area of the influence line diagram affected by the load, and this is somewhat of a tedious operation.

The writer found it a great convenience to prepare the tables described hereafter by which the various calculations can be rapidly accomplished.

In what follows two assumptions have been made, (1) that the centre line of the rib forms a parabola, and (2) that the moment of inertia of the cross-section of the rib is varied according to the tangential angle at the cross-section in question. In other words, if I_B is the moment of inertia of the cross-section at the crown, and I the moment of inertia at any other cross section, then :

$$I = I_B \text{ sec. } \theta.$$

where θ is the angle made with the horizontal by the tangent to the arc at the given cross section.

These assumptions are quite commonly made. The first allows of a simple equation for the locus of the centre line of the rib ; the second enables us to disregard the moment of inertia in the calculations and to measure distances along the span instead of along the rib.

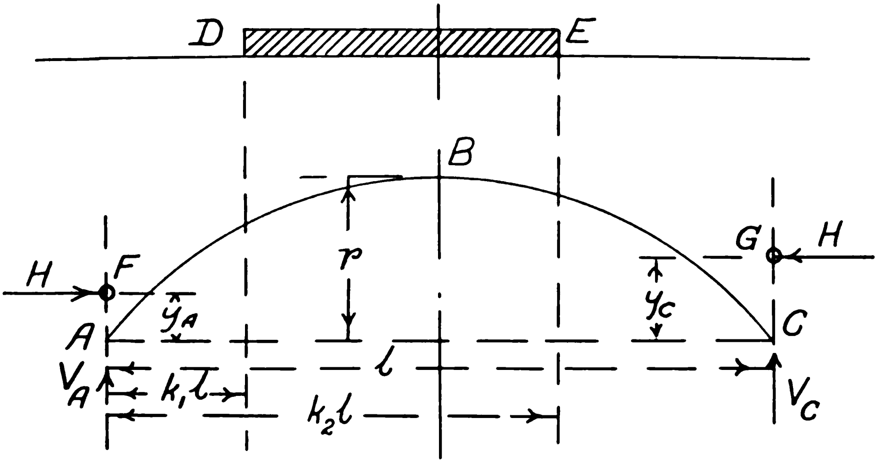


FIG 1.

Fig. 1 shows the centre line ABC of the rib, B being the crown. An external uniform load DE is placed so that the end D is at k_1l and the end E at k_2l from A. At some point F, at a height y_A above or below the springing

A, the resultant thrust can be resolved into a horizontal force H and a vertical force V_A. Similarly, at the right-hand abutment we have the vertical force V_C and a horizontal force H acting at a point G at a distance y_C above or below C.

Let a single unit load be supposed to be acting on the rib at a distance kl from the left abutment. Then it is proved in treatises on the theory of structures that the influence ordinates for y_A, y_C, H, V_A, and V_C have the following values :—

$$y_A = \frac{2r}{15k}(5k - 2)$$

$$y_C = \frac{2r(3 - 5k)}{15(1 - k)}$$

$$H = \frac{15l}{4r}(1 - k)^2k^2$$

$$V_A = (1 - k)^2(1 + 2k)$$

$$V_C = (3 - 2k)k^2$$

Also, if M_A, M_B and M_C denote the influence ordinates for the bending moments at the points A, B, and C, then :—

$$M_A = \frac{kl}{2}(5k - 2)(1 - k)^2$$

$$M_B = \frac{lk^2}{4}(10k - 3 - 5k^2)$$

$$M_C = \frac{lk^2}{2}(1 - k)(3 - 5k).$$

In order to utilise the influence line diagrams corresponding to the above values, the expressions must be integrated between the values k_1 and k_2. It is, however, only necessary to do this in the case of H, V_A, M_A and M_B. In all cases the point A is taken as the origin of co-ordinates.

In the case of M_A we have :—

$$\frac{l}{2}\int_{k_1}^{k_2} k(1 - k)^2(5k - 2)dx = \frac{l^2}{2}\int_{k_1}^{k_2} k(1 - k)^2(5k - 2)dk$$

$$= \frac{l^2}{2}\Big(k^5 - 3k^4 + 3k^3 - k^2\Big)_{k_1}^{k_2}$$

Similarly for M_B we have :—

$$\frac{l^2}{4}\left\{\frac{5}{2}k^4 - k^3 - k^5\right\}_{k_1}^{k_2}$$

For H we have :—

$$\frac{15l}{4r}\left\{\frac{k^3}{3} - \frac{k^4}{2} + \frac{k^5}{5}\right\}_{k_1}^{k_2}$$

and for V_A :—

$$l\left(k - k^3 + \frac{k^4}{2}\right)_{k_1}^{k_2}$$

The writer has summarised these values for every value of *k* from 0·01 to unity, as shown in the following tables. In using them the uniform load is supposed to extend from the left abutment to the point in question.

Table No. 1.—Summation of Influence Ordinates for the Bending Moment at the Crown $\left(\text{Multiply by } \frac{l^2}{4}\right)$.

k	0	·01	·02	·03	·04	·05	·06	·07	·08	·09
0	0	— ·00000098	— ·0000075	— ·000025	— ·000057	— ·00012	— ·00018	— ·00028	— ·00041	— 000·56
·1	— ·00076	— ·00098	— ·0012	— ·0015	— ·0018	— ·0022	— ·0025	— ·0029	— ·0034	— ·0038
·2	— ·0042	— ·0048	— ·0053	— ·0058	— ·0062	— ·0067	— ·0074	— ·0077	— ·0083	— ·0087
·3	— ·0092	— ·0095	— ·0097	— ·0102	— ·0104	— ·0105	— ·0106	— ·0107	— ·0107	— ·0106
·4	— ·0102	— ·0098	— ·0093	— ·0086	— ·0077	— ·0071	— ·0062	— ·0047	— ·0034	— ·0018
·5	0	+ ·0018	+ ·0034	+ ·0047	+ ·0062	+ ·0071	+ ·0077	+ ·0086	+ ·0093	+ ·0098
·6	+ ·0102	+ ·0106	+ ·0107	+ ·0107	+ ·0106	+ ·0105	+ ·0104	+ ·0102	+ ·0097	+ ·0095
·7	+ ·0092	+ ·0087	+ ·0083	+ ·0077	+ ·0074	+ ·0067	+ ·0062	+ ·0058	+ ·0053	+ ·0048
·8	+ ·0042	+ ·0038	+ ·0034	+ ·0029	+ ·0025	+ ·0022	+ ·0018	+ ·0015	+ ·0012	+ ·00098
·9	+ ·00076	+ ·00056	+ ·00041	+ ·00028	+ ·00018	+ ·00012	+ ·000057	+ ·000025	+ ·0000075	+ ·00000098
1·0	0									

Table No. 2.—Summation of Influence Ordinates for the Bending Moments at the left Abutment. $\left(\text{Multiply by } \frac{l^2}{2}\right)$.

k	0	·01	·02	·03	·04	·05	·06	·07	·08	·09
0	0	— ·0001	— ·0004	— ·0008	— ·0013	— ·0021	— ·0030	— ·0040	— ·0050	— ·0062
·1	— ·0073	— ·0086	— ·0099	— ·0112	— ·0125	— ·0139	— ·0152	— ·0166	— ·0179	— ·0192
·2	— ·0205	— ·0218	— ·0229	— ·0241	— ·0254	— ·0264	— ·0274	— ·0285	— ·0293	— ·0302
·3	— ·0309	— ·0317	— ·0324	— ·0329	— ·0334	— ·0337	— ·0341	— ·0343	— ·0345	— ·0346
·4	— ·0347	— ·0346	— ·0345	— ·0343	— ·0340	— ·0337	— ·0333	— ·0330	— ·0325	— ·0319
·5	— ·0313	— ·0304	— ·0296	— ·0290	— ·0282	— ·0274	— ·0266	— ·0258	— ·0248	— ·0237
·6	— ·0230	— ·0218	— ·0209	— ·0202	— ·0194	— ·0183	— ·0173	— ·0163	— ·0152	— ·0143
·7	— ·0134	— ·0127	— ·0119	— ·0109	— ·0097	— ·0088	— ·0082	— ·0074	— ·0067	— ·0061
·8	— ·0053	— ·0045	— ·0040	— ·0034	— ·0030	— ·0027	— ·0023	— ·0020	— ·0017	— ·0014
·9	— ·0013	— ·0011	— ·0009	— ·0007	— ·0006	— ·0005	— ·0004	— ·0003	— ·0002	— ·0001
1·0	0									

Table No. 3.—Summation of Influence Ordinates for the Horizontal Thrust at the Left Abutment. (Multiply by $\frac{15l^2}{4r}$. All values are +.)

k	0	·01	·02	·03	·04	·05	·06	·07	·08	·09
0	0	·0000003	·000003	·000009	·000021	·000042	·000072	·000114	·000171	·000243
·1	·000284	·00037	·00047	·00059	·00073	·00087	·00106	·00124	·00144	·00168
·2	·00193	·00219	·00249	·00280	·00312	·00326	·00382	·00418	·00458	·00500
·3	·0054	·0059	·0063	·0068	·0073	·0078	·0084	·0088	·0094	·0100
·4	·0106	·0111	·0117	·0123	·0129	·0136	·0142	·0148	·0154	·0160
·5	·0167	·0173	·0179	·0185	·0192	·0198	·0204	·0210	·0215	·0219
·6	·0227	·0233	·0239	·0244	·0249	·0254	·0260	·0264	·0269	·0274
·7	·0278	·0282	·0286	·0291	·0296	·0299	·0302	·0305	·0308	·0311
·8	·0314	·0316	·0318	·0320	·0322	·0324	·0325	·0326	·0328	·0329
·9	·0330	·0331	·0332	·0333	·0333	·0333	·0333	·0333	·0333	·0333
1·0	·0334									

TABLE NO. 4.—SUMMATION OF INFLUENCE ORDINATES FOR THE VERTICAL REACTION AT THE LEFT ABUTMENT. (Multiply by l. All values are +.)

k	0	·01	·02	·03	·04	·05	·06	·07	·08	·09
0	0	·0010	·0200	·0300	·0400	·0498	·0598	·0697	·0795	·0893
·1	·0990	·1087	·1184	·1279	·1374	·1469	·1562	·1655	·1747	·1838
·2	·1928	·2017	·2105	·2192	·2278	·2363	·2447	·2530	·2611	·2691
·3	·2770	·2830	·2925	·2999	·3073	·3146	·3217	·3287	·3355	·3422
·4	·3488	·3552	·3615	·3676	·3735	·3794	·3855	·3906	·3959	·4012
·5	·4062	·4111	·4159	·4205	·4250	·4293	·4336	·4376	·4415	·4451
·6	·4488	·4522	·4556	·4587	·4618	·4646	·4673	·4699	·4725	·4748
·7	·4770	·4791	·4811	·4830	·4847	·4862	·4878	·4892	·4905	·4917
·8	·4928	·4938	·4946	·4954	·4962	·4969	·4974	·4979	·4983	·4987
·9	·4990	·4993	·4995	·4996	·4997	·4998	·4999	·5000	·5000	·5000
1·0	·5000									

The use of the tables may be best shown by an example. Supposing we have a uniform load extending from a point $0{\cdot}23l$ to $0{\cdot}37l$ from the left abutment. To find all the data necessary in order to enable the line of thrusts to be drawn, we proceed as follows:

First with reference to the bending moment at the left abutment. Let the value of the load be w per unit length of span.

When $k = 0{\cdot}23$ the co-efficient from Table No. 1 is $-\,0{\cdot}0241$, and when $k = 0{\cdot}37$, it is $-\,0{\cdot}0343$. Thence the area of the influence diagram is $-\,0{\cdot}0343 + 0{\cdot}0241$ or $-\,0{\cdot}0102$. Hence the value of the bending moment at the left abutment is:—

$$-\,0{\cdot}0102\frac{wl^2}{2}$$

$$\text{or} -\ {\cdot}0051wl^2.$$

Similarly the bending moment at the crown will be:—

$$\frac{wl^2}{4}(-\,0{\cdot}0107 + 0{\cdot}0058) \text{ or } -\,0{\cdot}0024wl^2.$$

The value of H is:—

$$\frac{15l^2}{4r}(0{\cdot}0088 - 0{\cdot}0028)w$$

$$\text{or } +\,0{\cdot}0225\frac{wl^2}{r}$$

The value of V_A is:—

$$wl(0{\cdot}3287 - 0{\cdot}2192)$$

$$\text{or } 0{\cdot}1095wl.$$

It is now necessary to find the value of y_A. The bending moment at A is Hy_A, and this has already been determined as $-\,0{\cdot}0051wl^2$. We have also found the value of H to be $0{\cdot}0475\frac{wl^2}{r}$. Hence the value of y_A is:—

$$-\,0{\cdot}0051wl^2 \div 0{\cdot}0225\frac{wl^2}{r}$$

$$\text{or: } -\,0{\cdot}226r.$$

Thence the value of y_A is to be plotted below the springing line.

The line of thrusts can now be plotted. It may be checked by resolving the final force at the right-hand abutment and finding whether the horizontal component is still H. It would also be advisable to check the value of y_C. This may be done as follows:

If $(1 - k)$ be substituted for k in the value of y_A we obtain the value of y_C. Hence the ordinate diagrams for y_A and y_C are similar but reversed to each other. The value of H, when $k_1 = (1 - 0{\cdot}23)$ or $0{\cdot}77$ and k_2 is $0{\cdot}63$, is :—

$$\frac{15l^2}{4r}w(0{\cdot}0305 - 0{\cdot}0244)$$

$$\text{or } + 0{\cdot}0229\frac{wl^2}{r} \text{ approximately as before.}$$

The value of the bending moment at A would be :

$$\frac{wl^2}{2}(- 0{\cdot}0074 + 0{\cdot}0202)$$

$$= + 0{\cdot}0064wl^2.$$

Hence the value of y_C should be :—

$$+\frac{0{\cdot}0064wl^2r}{0{\cdot}0229wl^2}$$

$$\text{or : —} \quad + 0{\cdot}2794r.$$

The values given in the tables have all been plotted to a large scale to correct any accidental errors in the calculations. It is hoped that such summations will prove of utility to bridge engineers. Finally, should it be found practicable to make the dead load uniform throughout the span, the effect will be merely to add to the compressive stress and subtract from the tensile stress at all points along the rib.

Designing Concrete Mixtures.

Mr. A. E. Wynn, B.Sc., A.M.Am.Soc. C.E., writes as follows :—

"The following report may interest you, as showing the degree of accuracy obtained by designing concrete mixtures by the water ratio theory, as outlined in my article.[*]

"When the instruction class in this subject was held in Syracuse, and attended by over 200 engineers, the lecturer designed a mixture using local gravel (which was not particularly good) and local sand, designing for a minimum strength of 2,500 lbs. and an average strength under controlled conditions of 3,050 lbs., or 550 lbs. greater, according to curves A and B.

"The design was made in the same way as the example I took, only measurements were by weight instead of using the field testing set. No particular care was taken, it being the object to approximate field conditions as closely as possible.

"Three test cylinders were made up and have just been tested at twenty-eight days with the following results :

Cylinder No.	Breaking strength at 28 days in lbs. per sq. in.	Variation from average. Per cent.
1	3,080	minus 1
2	2,925	,, 6
3	3,345	plus 7
Average	3,116	,, 5

"The value of 3,116 lbs. locates the job curve slightly higher than curve A. Variation from the average should be within 10 per cent.; in the above case it is about 7 per cent. maximum."

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[*] "Concrete and Constructional Engineering," June, July and August, 1926.

British Standard Specification for Portland Blast-Furnace Cement.

THE British Engineering Standards Association has published a new issue of the British Standard Specification for Portland Blast-Furnace Cement (No. 146, 1926) which was first issued in 1923. The modifications follow precisely the same lines as those introduced into the current issue of the B.S. Specification for Portland Cement issued in 1925.

The following are the principal alterations embodied in the 1926 edition of Report No. 146:—

(1) A summary of the tests is given at the beginning of the Specification.

(2) Provision has been made for testing in hot countries at temperatures up to 95 degrees Fahrenheit. In climates where the temperature runs above 95 degrees or below 58 degrees special arrangements have to be made between the vendor and the purchaser unless the ranges given in the Specification can be artificially produced.

(3) The cement is now required to be more finely ground, the permissible residue on a 180 × 180 sieve being 10 per cent. instead of 14 per cent. Tolerances are laid down for the number and size of wires and size of openings in sieves both for cement and for sand. The minimum size of the sieving area is now specified to be 50 square inches and the minimum depth of the sieves to be 2¾ ins.

(4) The maximum figure for the hydraulic modulus of the Portland cement clinker has been raised to 2·90, and the maximum limit for magnesia is now 4 per cent.

(5) The minimum tensile breaking strength of neat cement after 7 days has been increased to 600 lbs. per sq. in., and that of cement and sand after 7 days to 325 lbs. per sq. in. The 28-day test on neat cement has been eliminated.

(6) The amount of water for gauging cement and sand briquettes is now to be ascertained by means of a formula based upon the amount needed to produce the plastic mixture required in the tensile test for neat cement.

(7) The standard Leighton Buzzard sand is required to be of the white variety, and its loss of weight on extraction with hot hydrochloric acid is specified not to exceed 0·25 per cent.

(8) The initial setting time of normal setting cement is to be not less than 30 minutes and the initial setting time of quick-setting cement not less than 5 minutes.

Copies of this publication can be obtained from the B.E.S.A. Publications Department, 28 Victoria Street, S.W.1 (price 1*s.* 2*d.* post free).

Effects of Storage on Cement.

PROFESSOR O. GRAF has recently described in *Beton u. Eisen* a series of tests on fifteen brands of German cement which had been kept for a long period at the Stuttgart Technical High School. The cements were stored in bags in a position free from damp and other causes which could damage their strengths.

As a result of his tests, Professor Graf found that the Portland cements only lost a small proportion of their strengths after four to six years' storage, while slag cements began to lose strength after a period of three months, while after 3½ years they were only half as strong as in their initial stage.

One peculiar result was noted in testing a Portland cement which had been stored for six years and contained hardened pieces which could only be broken by a hammer, indicating that setting had started in this bag. The remaining cement gave a final strength at six years of 5,850 lbs. per sq. in. compared with 5,800 at three months.—W.S.G.

Unusual Design of Tall Reinforced Concrete Building.

THE Detroit Towers Apartment Building was the subject of a paper read recently by Mr. W. F. Zabriskie (Vice-President of the Gabriel Steel Company, who were responsible for the structural design).

This building, he said, is believed to mark a distinct point in the advance in the use of reinforced concrete construction in buildings of more than usual height. While definite data are lacking, the writer has been unable to discover records of any other building built of an equal height throughout its entire area.

A point out of the ordinary is the proportion of height to breadth, and its relation to the design of the wind-bracing in the frame. Considering all these points, it appears evident that if reinforced concrete can be successfully and economically used in such a structure it is worthy of being given serious consideration as a form of construction to be used in high buildings generally.

In plan, the building has a length of approximately 105 ft. with a width at the south end of 60 ft. and at the north end of 44 ft. There are about 5,400 sq. ft. of floor per story. There are, in all, nineteen stories above ground.

The building is on the bank of a river. The soil conditions, as disclosed by preliminary borings, indicated the advisability of piling, and test piles were driven to determine in advance the proper length. There were, in all, 627 timber piles used, varying in length below cut-off from 35 to 45 ft., the longer piles being used on the river end of the structure. The pile cut-off was approximately 6 ft. below the existing grade, and below the mean water line. The pile capacity used in foundation design was twenty tons per pile.

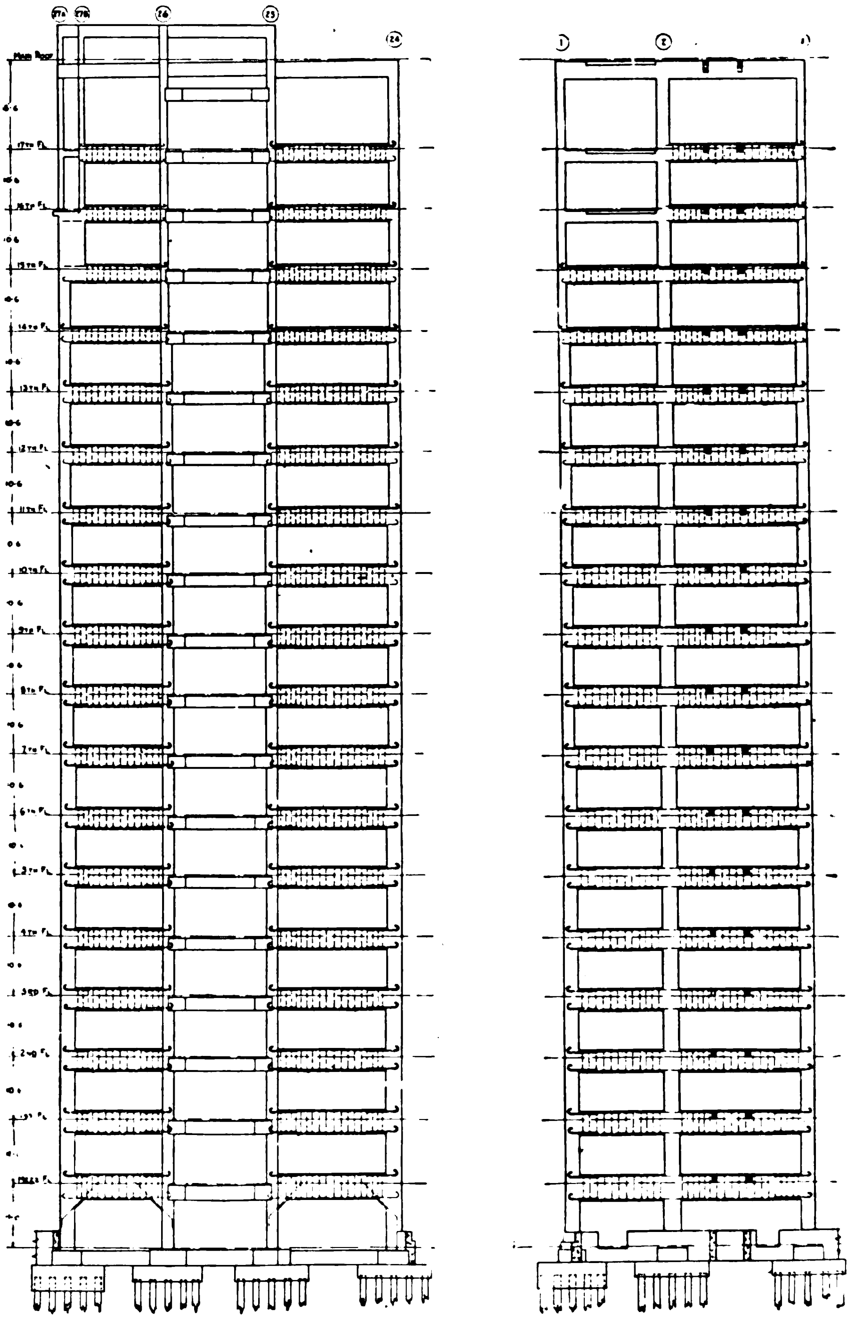
The general type of floor construction was given thorough study. It was considered very essential to keep all dead loads to the minimum in order to prevent excessive size of the columns. The floor construction finally adopted was an 11-in. plus 2-in. removable steel floor tile design with interior girders 13 in. in depth, and concealed in the thickness of the floor slab. This arrangement seemed to be necessary in order to prevent interference of beams with the room plan, which was very irregular, and which precluded the possibility of beams projecting below the slab in most locations.

The architect's plans called for finished hardwood floors in all principal rooms. In order to avoid the weight of any form of sleeper fill, wooden sleepers were anchored to structural concrete slabs by means of sheet metal anchors cast in the slab. As the finished flooring was laid the space between sleepers and under the floor was filled solidly with mineral wood to serve as a sound-deadening material and a fire resister. The weight of the entire floor finished was assumed in the load calculation as 6 lbs. per sq. ft. Metal lath and plaster ceilings were provided throughout, attached directly to the underside of the concrete floor slab.

Wind-bracing in the north and south directions was provided for entirely in the exterior columns and spandrel beams. Wind-bracing in an east and west direction was provided for in the line of the north and south walls, and by two rows of interior columns where it was possible to permit the beams to project below the floor slab.

Spandrel beams were made of a uniform thickness of 8½ in. so that they were entirely concealed inside the brick enclosing wall. On account of the fact that the larger part of the wind stresses was carried by the spandrel construction, these beams were of considerable depth, the deepest beams being 52 in. The bottoms of the spandrel beams were in all cases located to serve as lintels over the various window openings. In the design of the columns it was necessary to adapt their form to fit conditions caused by the architectural floor plans. Most of the exterior columns were made rectangular in form with the long dimension of the rectangle parallel with the wall. The maximum load carried by any column was 1,148,000 lbs. In order to keep the columns to a minimum size a 1 : 1 : 2 mix was used for the lower eleven stories. Approximately 4 per cent. of verticals were used in lower sections of columns.

The size of the base section of the most heavily loaded columns was 33 in. square. Other heavily loaded columns were rectangular in form but of approximately the same area. Although these columns



SOUTH FRAMING ELEVATION

NORTH FRAMING ELEVATION

Framing Elevations, showing Deep Spandrel Beams providing Wind Bracing in Outer Bays.

are of more than ordinary size, it was possible to arrange the partitions so that the columns did not interfere with the lay-out of the rooms. In the complete structure it is surprising how inconspicuous the columns are in any room.

In the cases of many of the columns the stresses due to flexure were a large factor in the design of the column. In these cases reinforcing bars were placed so as to give a maximum value of resisting moment for the column. Detailed plans were prepared, showing spacing of column bars and dowels for all such cases.

The reinforced concrete work was designed, in general, in accordance with provisions of the Detroit Building Code, which permits a tensile stress of 20,000 lbs. per sq. in. for intermediate grade billet steel. The maximum compressive stress in stayed columns was 675 lbs. per sq. in. The maximum compressive stress on 1 : 2 : 4 concrete in flexure was 750 lbs. per sq. in. All stresses were increased by 35 per cent. for combined wind and direct loads.

Field control of the concrete was obtained by slump tests taken throughout the progress of the concreting operations. A slump of between 5 and 6 in. was obtained in pouring the steel tile floor slabs and a slump of approximately 4 in. was used in pouring columns and beams. A small quantity of hydrated lime was used throughout, the quantity being from 5 to 7 per cent. by weight of the cement. Six-inch by six-inch test cubes were taken from both slab and column concrete and crushed after 28 days. Cubes of column concrete tested between a minimum of 2,800 lbs. per sq. in. and a maximum of 3,870 lbs. per sq. in., averaging over 3,000 lbs. per sq. in.

Comparative Cost of Concrete and Steel.

While the project was in preliminary form, several tentative designs were considered, including a complete steel frame and a composite frame, using structural steel in the lower stories. Since the final design varied greatly from preliminary studies, a complete new estimate was made of the structural steel work as a matter of ascertaining the comparative costs. The following tabulation is submitted to show the relative cost of the construction with what the cost would have been had a structural steel frame been employed :

CONCRETE FRAME DESIGN (AS CONSTRUCTED)

		$
Piling		12,500
Pile Capping—484 yards, including Excavation and Forms		9,500
Column Concrete—		
1 : 1 : 2 617 yards at $11.50	$7,095.50	
1 : 1½ : 3 222 yards at 10.50	2,331.00	
1 : 2 : 4 38 yards at 9.00	342.00	
		9,768
Column Forms—24,000 square feet at 0.25		6,000
Floor and Beam Construction—2,631 yards		24,995
Floor and Beam Forms—including Removable Steel Tile		25,200
Reinforcing Steel—including Engineering		27,450
Placing Reinforcing Steel—370 tons at $15		5,725
		$121,138

Total Yards of Concrete—3,992 Cubic Yards

STEEL FRAME DESIGN

	$
Piling	11,800
Pile Capping—including Excavating and Forms	8,900
Column Fireproofing—1 : 2 : 4 434 yards at 9.00	3,906
Column Forms—including Brackets for Wind Bracing—18,000 at 0.25	4,500
Floor Concrete and Beam Fireproofing	24,995
Floor and Beam Forms—including Removable Steel Tile	23,800
Structural Steel—including erection—900 tons at $90	81,000
Reinforcing Steel—100 tons	6,800
Setting Reinforcing Steel—100 tons at $15	1,500
Engineering Design	4,000
	$171,201

It will be noted that there is an indicated saving of approximately $50,000 by the use of reinforced concrete. This amounts to a saving on the cost of the structural frame of approximately 30 per cent. Looking at it from another angle, it means that the cost of the structural frame would have been increased approximately 42 per cent. had structural steel been employed instead of reinforced concrete.

In addition to the large saving indicated, the contractors state that they believe time was actually saved in the construction of the building due to the selection of reinforced concrete. This is due to the fact that the construction was begun almost simultaneously with the preparation of the design. It would therefore have been impossible to have obtained base sections of the structural steel columns, fabricated them, and commenced erection when the pile cappings were completed and ready to receive steel work.

Although the building was of an unusually complicated construction, very few difficulties arose. The first piles were driven March 1 and pouring of the roof slab was completed on August 10. Unless delayed by unusual weather, the floors were completed on the average of one every five days. The brick masonry followed the pouring at about the same rate of progress. It was generally about five or six floors below the story being poured. Final brick work was completed on September 19. The interior partitions were carried up at about the same rate as the brick enclosing walls.

The architect was Mr. Walter W. Ahlschlager of Chicago. All construction work was performed by the Walbridge-Aldinger Company, of Detroit.

A Reinforced Concrete Race-Stand in Argentina.

Concrete Roads in Eight Countries.

REPORTS TO THE INTERNATIONAL ROADS CONGRESS.

As has been the case for several years now, the chief interest of the delegates to the International Roads Congress, held in Milan last week, lay in the all-concrete road. More reports dealt with this subject than with any other aspect of the road problem. Reports on the progress made in the construction of all-concrete roads were received from Great Britain, the United States, France, Belgium, Sweden, Italy, Denmark, and Holland, and all showed that this class of road is standing up well to the various types of traffic put upon it, and that the authorities are so satisfied with the results that they are extending their all-concrete road programmes.

As the reports deal with practically every aspect of concrete road problems, we give extracts from them, chiefly confined to the parts which have not hitherto been published in this country.

Great Britain

Mr. Arthur Harrison, M.Inst.C.E., Borough Surveyor of Southwark, Mr. J. B. L. Meek, M.Inst.C.E., City Engineer of Manchester; Mr. W. P. Robinson, A.M.Inst.C.E., County Surveyor of Surrey; and Mr. W. S. Richmond, C.M.G., A.M.Inst.C.E., Divisional Road Engineer of the Ministry of Transport, are the reporters for Great Britain.

Southwark.—Mr. Harrison points out that 105 short streets, with a total length of 11¾ miles, have been reconstructed in concrete in Southwark since three experimental streets laid in 1919 were found to be satisfactory:

Method of Construction.—The method of construction adopted is as follows:

The surface of the old macadam roads is excavated to an average of 9 in., and the new surface trimmed to an even grade showing a slight camber. The excavated material is passed through a washing machine on the site which cleans and grades the material, giving a salvage of the total excavation of 90 per cent. in the following proportions:

	Per cent.
Stone 2 in. to ¾ in. gauge	18
Coarse sand and grit ⅜ in. gauge	62
Fine sand	20

To the stone is added sufficient of the sand and grit to produce an aggregate practically clear of voids, generally in the proportion of 2 to 1. The concrete is thoroughly mixed by hand in a dry state and afterwards turned over three times wet. The lower course is composed of 6 parts of aggregate to 1 part of Portland cement, laid to a depth of 4½ in., or 1½ in. below the finished surface of the road. The upper course is composed of 3 parts crushed granite to 1 part cement. The crushed granite aggregate is graded as follows:—

	Per cent.
¾ in. to ½ in.	8
½ in. to ¼ in.	17
¼ in. to dust	75

The quantity of water used in each case is approximately 7 gallons and 4½ gallons per cu. ft. of cement in the mixture for fine and rough concrete respectively.

Immediately after the lower course has been laid, the upper course is placed in position to a depth of 1½ in., both operations following on yard by yard in order to produce one homogeneous mass. The surface is rammed with hand tampers, and a light roller is drawn across the road to take away any surplus water which may have risen to the face.

The lower course has 5 in. square mesh reinforcement composed of $\frac{3}{16}$ in. mild steel bars placed 1½ in. above the soffit of the concrete. The finished road thus formed consists of an average of 6 in. of consolidated reinforced concrete, the haunch of the road being about 7 in. thick and the crown about 5½ in. thick.

The quality of the concrete to resist surface wear as distinct from failure by crushing must be provided for, and this point has to a great extent been met by the use of the crushed granite aggregate in the wearing course and by the surface treatment referred to later.

The concrete is laid in a continuous length and at completion of each day's work the slab is finished with a clean vertical joint formed at an angle 1 in 3 to the line of the kerb. The slabs thus formed vary from 60 ft. to 80 ft. in length by 20 ft. in width. The joint is formed obliquely to the line of the kerb in order to prevent two wheels of a vehicle striking the joint at the same moment, and thus distribute the load over the joint. Each slab or bay is entirely disconnected from the adjoining bays. A slip of bituminous compound $\frac{1}{16}$ in. thick is placed against the vertical face of the slab forming the end of the previous day's work in order to form the joint from which contraction takes place, and the new concrete is butted against this bituminous slip. In continuation of the work the slip is afterwards burred over the joint.

With a view to the work being carried out in continuous lengths the contour of the road is formed by pegging the levels and working to the pegs by hand tampers. The tamping tool is in the form of a flat plate 14 in. by 13 in. by ¼ in. fixed obliquely to a shaft 5 ft. long, and the men using these tools are trained to work by eye to level pegs.

Curing.—The curing of the concrete is a point to which a considerable amount of importance is attached. As the initial set commences the concrete surface is covered with a layer of fine sand to a depth of about 2 in. and this is kept damp for fourteen days. The sand is then removed and the surface is washed and allowed to dry, after which a dressing is applied of a solution of four parts water to one part silicate of soda. Three applications of this dressing are given at intervals of twenty-four hours. The roads are opened to traffic three weeks from the laying of the concrete.

A section of concrete road treated with silicate of soda subsequently carried traffic of over 22,000 tons per week, a large percentage of which consisted of steel tyred vehicles. At the end of twelve months the results were very satisfactory and all similar work in Southwark is now treated with a silicate of soda solution. This treatment is found to have the effect of hardening the face of the concrete to a depth of about ¼ in. and also closes the pores of the face, the action being the combination of the silicate of soda with the free lime liberated in the setting of the cement. It has also been proved that considerably less contraction has taken place in the case of roads treated with silicate of soda as compared with those not so treated, and the joints between bays are less prominent.

Repairs.—The reinstatement of trench openings is always an important one. With a view to expediting repairs the method now adopted in Southwark consists of the use of pre-cast concrete slabs 2 ft. 6 in. by 2 ft. by 4 in. deep. These slabs are inserted in the opening, the concrete road being cut back to the size of the slab and a new slab bedded on rich rapid-hardening cement mortar placed just above the reinforcement. This method has proved expeditious and quite satisfactory.

Generally.—It is considered that the adoption of concrete roads in Southwark has solved the problem of improving roads in the Borough, and moreover has found useful employment for a large number of untrained men out of work. Little or no trouble has however been experienced due to climatic conditions as the curing cover has proved sufficient protection from frost. In the case of the few roads constructed during summer months, although the concrete was carefully protected from the sun's rays, results have not proved so satisfactory as for roads constructed during the winter. It is also noticeable that in summer work there is more contraction in the bays, resulting in more open joints. These results would appear to show that in the early days sun is a greater enemy to concrete than frost.

Manchester.—Mr. J. B. L. Meek confined his report principally to a comparison of the costs of different types of concrete roads laid in Manchester under conditions which gave exceptionally good opportunities for such a comparison to be made. Six different types are covered, each built in 1920 by the same workmen and at the same time of the year. The costs were as follows:

Section No. 1.—6 in. thick; bottom layer 4 in. thick of 6 to 1 concrete made with fairly hard flag rock, 1½ in. gauge, and local sand which is by no means sharp; top layer 2 in. thick of 3 to 1 concrete made with granite, ¾ in. gauge, and local sand. No reinforcement.

	£	s.	d.
Labour and carting	19	1	8
Excavating	14	1	11
Concreting	220	12	0
Watching	28	19	8
	£282	15	3

Area 289 sq. yds.; cost per sq. yd. = 19/7.

Section No. 2.—4 in. thick of 6 to 1 concrete made of granite, 1½ in. gauge.

and local sand laid in one course. Reinforced with single mesh reinforcement, with 1 in. of cover in the lower part of the concrete.

	£	s.	d.
Labour and carting	22	16	7
Excavating	5	12	4
Concreting and reinforcement	272	0	3
Watching	31	4	9
	£331	13	11

Area 310 sq. yds.; cost per sq. yd. = 21/6.

Section No. 3.—6 in. thick of 6 to 1 concrete, laid in one course. Reinforced with single mesh reinforcement. Concrete composed of 1½ in. gauge granite and local sand; reinforcement 2 in. from bottom of concrete.

	£	s.	d.
Labour and carting	23	11	10
Excavating	5	15	0
Concreting and reinforcement	283	15	4
Watching	30	1	10
	£343	4	0

Area 306 sq. yds.; cost per sq yd. = 22/5.

Section No. 4.—8 in. thick; bottom layer 5½ in. thick of 6 to 1 concrete made with fairly hard flag rock, 1½ in. gauge, and local sand; top layer 2½ in. thick of 3 to 1 concrete made with granite, ¾ in. gauge, and local sand. No reinforcement.

	£	s.	d.
Labour and carting	44	4	6
Excavating	48	3	8
Concreting	445	17	1
Watching	45	0	10
	£583	6	1

Area 485 sq. yds.; cost per sq. yd., 24/6.

Section No. 5.—6 in. thick of 6 to 1 concrete, composed of granite, 1½ in. gauge, and local sand, laid in one course. No reinforcement.

	£	s.	d.
Labour and carting	29	2	11
Excavating	19	15	3
Concreting	219	11	3
Watching	29	0	3
	£297	9	8

Area 290 sq. yds.; cost per sq. yd. = 20/6.

Section No. 6.—6 in. in total thickness, in two courses and reinforced with single mesh reinforcement laid 2 in. from bottom of concrete; bottom layer of 6 to 1 concrete made with granite, 1½ in. gauge, and local sand; top layer of 3 to 1 concrete made with granite, ¾ in. gauge, and local sand.

	£	s.	d.
Labour and carting	20	3	5
Excavating	13	8	2
Concreting and reinforcement	314	13	2
Watching	30	9	9
	£378	14	6

Area 311 sq. yds.; cost per sq. yd. = 24/4.

The sections are all on gradients varying from 1 in 99 to 1 in 46. The camber is 1 in 60. The road was tar-sprayed several times, but very little of the covering remained for more than a month or two, and for some time now the concrete has been uncovered. All the concrete was hand mixed. The road is just outside a large engineering works and carries a traffic of 13,433 tons per yard width of carriageway per annum, or 340 vehicles per day of 16 hours. Sections Nos. 1 and 4 were laid on the alternate bay system, and Sections Nos. 2, 3, 5 and 6 were laid on the continuous system, a straight joint being left at the end of each day's work. No repairs have been done up to date, and the sections are in excellent condition with one or two exceptions, and these exceptions are still a long way from requiring repairs.

The total length of the sections is 244·37 yards, and only one crack has appeared in the whole length. This crack is in Section No. 4, longitudinally across one of the alternate bays at a place where a water hydrant box occurs in the road. At the commencement of Section No. 1, two small places show signs of wear which may be put down to the change of surface from setts to concrete and the consequent impact of the traffic. In the alternate bay sections the joints show signs of wear, while in the continuous sections no such signs appear. The surface of the sections where 1½ in. gauge stone was brought to the surface has worn slightly rougher than the surface of the sections topped with ¾ in. gauge stone. There is no perceptible difference between the reinforced and unreinforced sections.

The conclusions to be drawn from the experimental sections are:

(1) Where the width of the carriageway is not too great to permit a template being used from kerb to kerb, continuous work is more satisfactory than alternate bay work on account of the less number of joints.

(2) On a good foundation reinforcement is neither necessary nor economical.

(3) The surface of the road keeps its appearance better if small aggregate is used in the top two inches of the road.

(4) At changes of road surfaces or where impact from traffic is likely to occur the concrete should be very carefully laid and be 3 in. thicker than the normal thickness of the road.

Since these sections have been constructed sharp granite sand has been used for surfacing in place of the fine local sand with very satisfactory results.

Cost in 1925.—It may be interesting to give the cost of a concrete carriageway constructed in 1925; the cost is for concrete only—excavation, watching, removing old setts, etc., being omitted. The road was 7 in. thick in two courses, not reinforced. The bottom 5 in. is 6 : 1 concrete made with flag rock, 1½ in. gauge, and pit sand; the top 2 in. is 3 : 1 concrete made with granite chippings and granite sand. The area of the work is 1306 sq. yards.

	Total Cost.			Cost per sq. yd.		
	£	s.	d.	£	s.	d.
Labour	85	14	8	1	3	7·6
Concrete Mixer, 14 days 10*s*. . £7 0 0						
Attendant . . £7 5 4						
	14	5	4		2	6·2
Carting	36	1	9		6	6·3
Cement	194	12	8	2	11	7·7
Broken Stone . . .	73	8	2	1	1	4·9
Sand	20	17	11		3	8·4
Granite (including loading)	77	2	4	1	2	1·7
Handling charges on Materials ex Depots 10%	8	7	11		1	5·4
	£510	10	9	£7	9	8·2

Surface Covering.—The difficulty of obtaining a suitable, cheap and reasonably durable surface covering for a concrete road has not yet been overcome. Spraying the road with a mixture of pitch and creosote oil, and afterwards covering with chippings, is not satisfactory, as no matter how clear the road is the majority of the material does not stick to the surface for any length of time. Two curious facts about this tar-spraying are that the second application generally remains down longer than the first, and the third longer than the second; also that when a small patch of the material does stick to the road surface the adhesion is good. Many proprietary materials have been tried as coverings for concrete roads, but so far none has been any more successful than the mixture of pitch and oil. Rubber-tyred vehicles do not damage an uncovered concrete road, but worn steel tyres, and particularly horses' hoofs, do damage by picking small stones out of the surface and thus commencing wear; a covering would be some protection against this, and also protect the joints from wear.

Repairs.—Repairs to a concrete road are rendered fairly simple and cheap by the use of pneumatic tools and rapid hardening cement. By these means traffic can pass over ordinary small patches within 24 hours of the work being commenced. Although rapid-hardening cement is more expensive than ordinary cement, the extra outlay is easily recovered by the reduction in watching and the convenience of the public.

Surrey.—Mr. W. P. Robinson stated that so far 20 miles of all-concrete roads have been laid in Surrey, mostly on new arterial and by-pass roads. These roads are all on the alternate bay system; the positions of the joints and lay-out of reinforcement are shown on p. 640.

Method of Construction.—The sub-soil is shaped and consolidated by rolling to a camber of 1 in 50 and covered with a layer of clinker or ashes not less than 3 in. thick properly consolidated. The concrete is laid thereon to a thickness of 8 in. in two courses. The lower course is 6 in. thick composed of 5 parts of aggregate, 2½ parts of sand, and 1 part of slow-setting Portland cement. The upper course is 2 in. thick, composed of 3 parts of aggregate, 1½ parts of sand, and 1 part of Portland cement.

The aggregate consists of washed and crushed gravel graded as follows:

	Per cent. by weight.
Passing a 1 in. ring and rejected by a ½ in. ring.	60
Passing ½ in. ring and rejected by an ⅛ in. ring	40

The sand is washed and screened to the following grading within a margin of 5 per cent.

	Per cent.
Passing 10 mesh and rejected by 30 mesh	55
Passing 30 mesh and rejected by 80 mesh	30
Passing 80 mesh and rejected by 100 mesh	15

The concrete is machine mixed in a batch mixer, each batch occupying a period of about 80 seconds in mixing.

The bays are formed by timbers temporarily fixed along the outer edges of the carriageway and in the position of each joint. A layer of concrete 1½ in. thick is laid and rammed by hand over the whole area of a bay. Steel reinforcement in the lower layer is then placed in position, followed by a further layer of concrete 4½ in. thick laid and rammed to receive the upper layer of steel reinforcement, upon which is superimposed the upper course, or surface, which is tamped with a steel-shod timber beam, this tamper being kept parallel to the centre line of the road.

The quantity of water used is the minimum amount required to give a plastic mix.

About six hours after laying the concrete the surface is brushed with stiff wire brooms and immediately covered with a layer of soil not less than 3 in. thick, which is kept damp by watering for a period of at least 28 days.

A period of not less than 14 days is allowed to elapse before the intermediate bays are laid, and these are tamped and finished level with the bays previously laid.

The transverse joints are formed at an angle of 60 deg. to the centre line of the road, and are plain vertical joints; the timber used for supporting the bays first laid is removed before filling in the intermediate bays.

The lower layer of reinforcement is 1½ in. above the underside of the concrete, and the upper layer of reinforcement 1½ in. below the finished surface.

On pp. 641 to 644 are the details of the sizes and spacing of the steel bars used in four distinct types, the type used being determined after consideration of the prevailing conditions. The reinforcement is continued through the joints between bays with the object of avoiding unequal settlement of adjacent slabs and distributing the pressure exerted on the subsoil by the moving weight of traffic.

Surface dressings of tar and bitumen have been applied with the object of waterproofing the concrete, but difficulties have been experienced in securing satisfactory adhesion. It has been found that a dressing of oil is effective for waterproofing purposes without affecting the strength of the concrete.

A length of 1½ miles of the Reigate-Dorking Road was opened to traffic in June 1923, and 1¾ miles were opened in October 1924. The weight of traffic passing over the first-opened section as recorded by a census taken in August 1925 amounts to 2,580 tons per day of 16 hours.

The Bagshot By-Pass was opened to traffic in October 1925; the estimated weight of traffic passing over it amounts to 5,088 tons per day of 16 hours.

The two road diversions near Chobham (No. 5) were opened to traffic in October 1925; the estimated weight of traffic passing over them amounts to 1,069 tons per day of 16 hours.

Observations and Conclusions.—Among some conclusions given by the author are the following:—

For the wearing surface the gauge of the aggregate should not exceed ¾ in., suitably graded downwards.

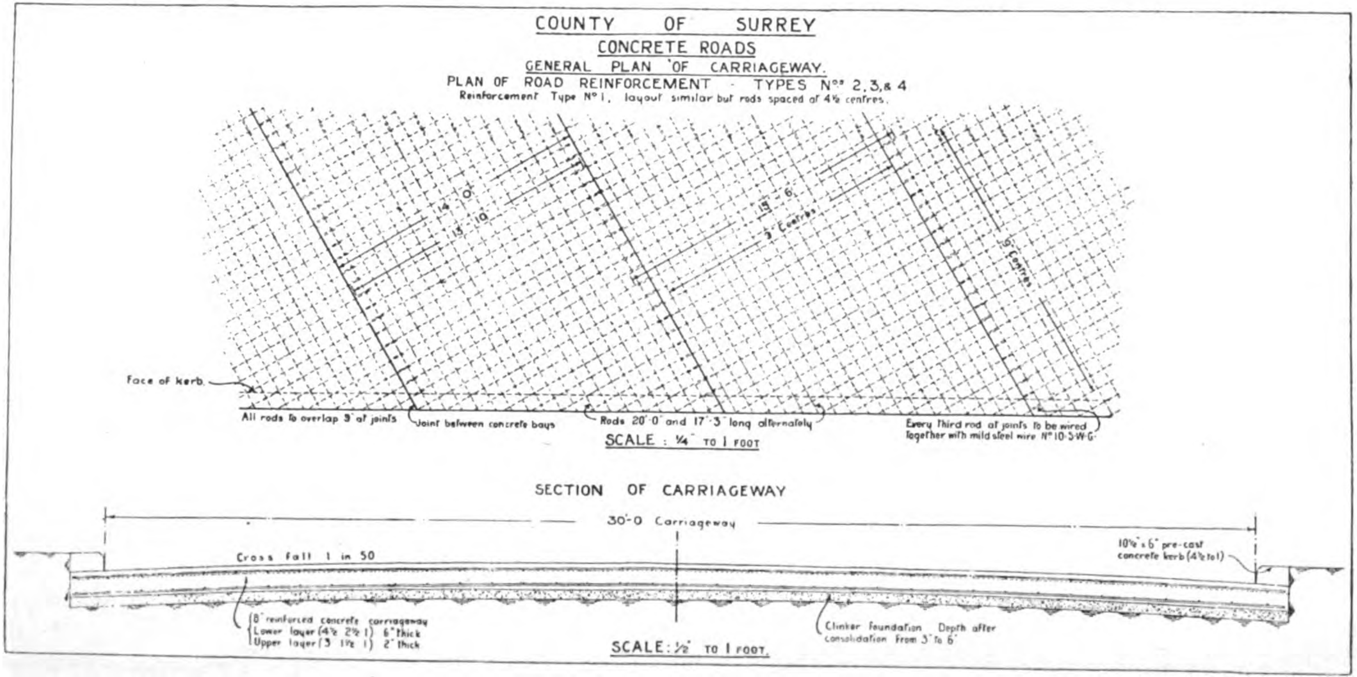
Where two-course construction is adopted a larger gauge may be used in the lower course, but in determining this gauge consideration should be given to the placing of the reinforcement (if used) in relation to the underside of the concrete.

For roads carrying steel tyred vehicles the aggregate for the wearing surface should be specially selected for resistance to wear. It is considered that granite is the most suitable material to meet these conditions.

On a good foundation it is doubtful whether reinforcement is necessary or economical. Its presence does not appear to prevent failure by cracking of the concrete, although it may be considered to influence the type and position of cracks in the concrete on unsuitable subsoils or those which are difficult to consolidate uniformly.

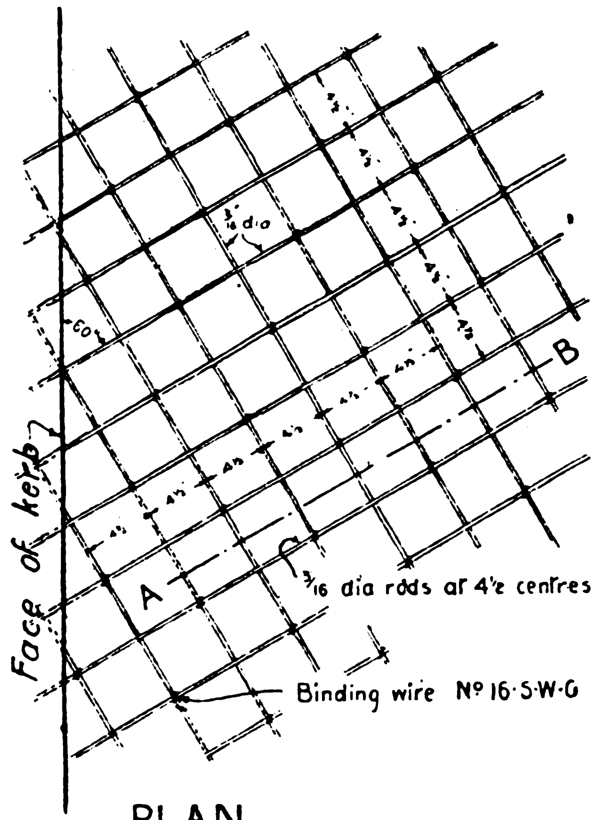
The following reasons may be submitted in favour of the use of reinforcement:

(*a*) It assists in preventing unequal settlement and if cracks appear in the concrete it assists in preventing or delay-

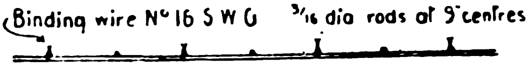

COUNTY OF SURREY
CONCRETE ROADS
GENERAL PLAN OF CARRIAGEWAY.
PLAN OF ROAD REINFORCEMENT - TYPES N^os 2, 3, & 4
Reinforcement Type N° 1, layout similar but rods spaced at 4½ centres.
14'-0"
15'-10"
15'-6"
3' Centres
9' Centres
Face of kerb.
All rods to overlap 9" at joints
Joint between concrete bays
Rods 20'-0" and 17'-3" long alternately
Every third rod at joints to be wired together with mild steel wire N° 10-S-W-G-
SCALE : ¼" TO 1 FOOT
SECTION OF CARRIAGEWAY
30'-0 Carriageway
Cross fall 1 in 50
10½" x 6" pre-cast concrete kerb (4½ to 1)
8" reinforced concrete carriageway
Lower layer (4½ 2½ 1) 6" thick
Upper layer (3 1½ 1) 2" thick
Clinker foundation Depth after consolidation from 3" to 6"
SCALE : ½" TO 1 FOOT.

General Design of All-Concrete Roads in Surrey.

SINGLE LAYER REINFORCEMENT
TYPE No. 1

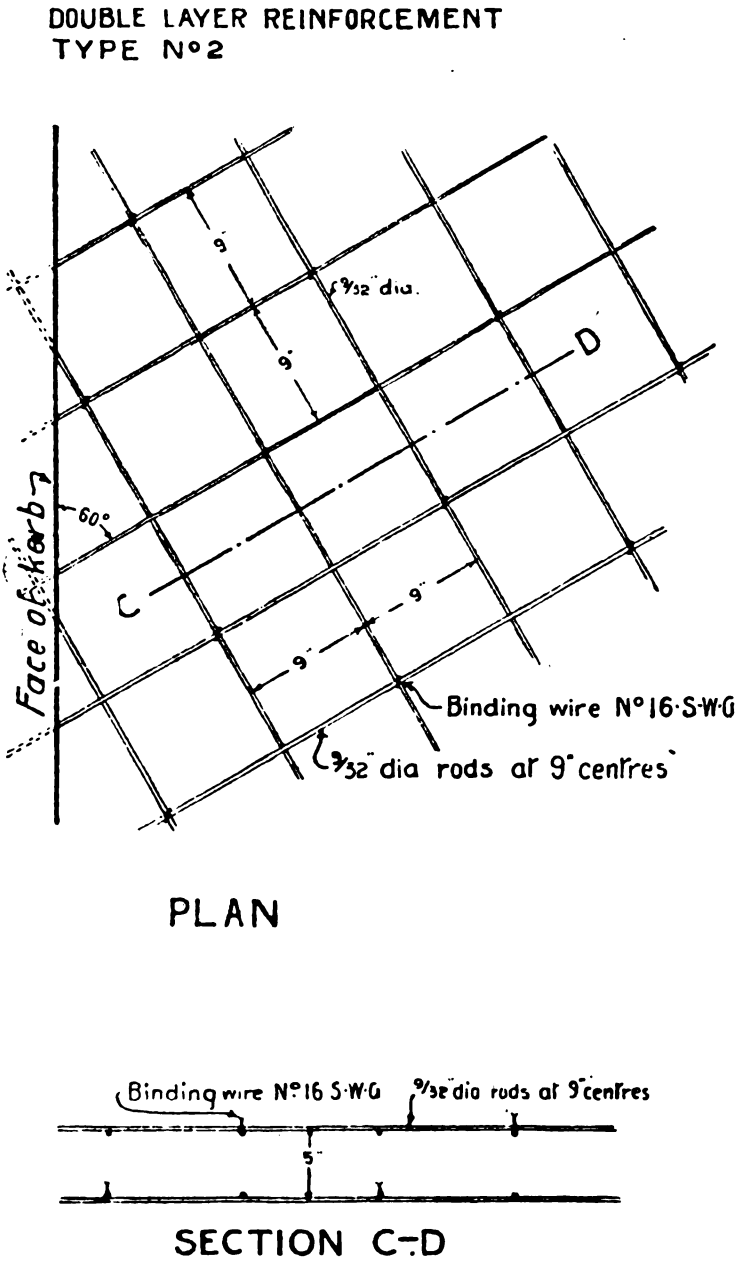


PLAN

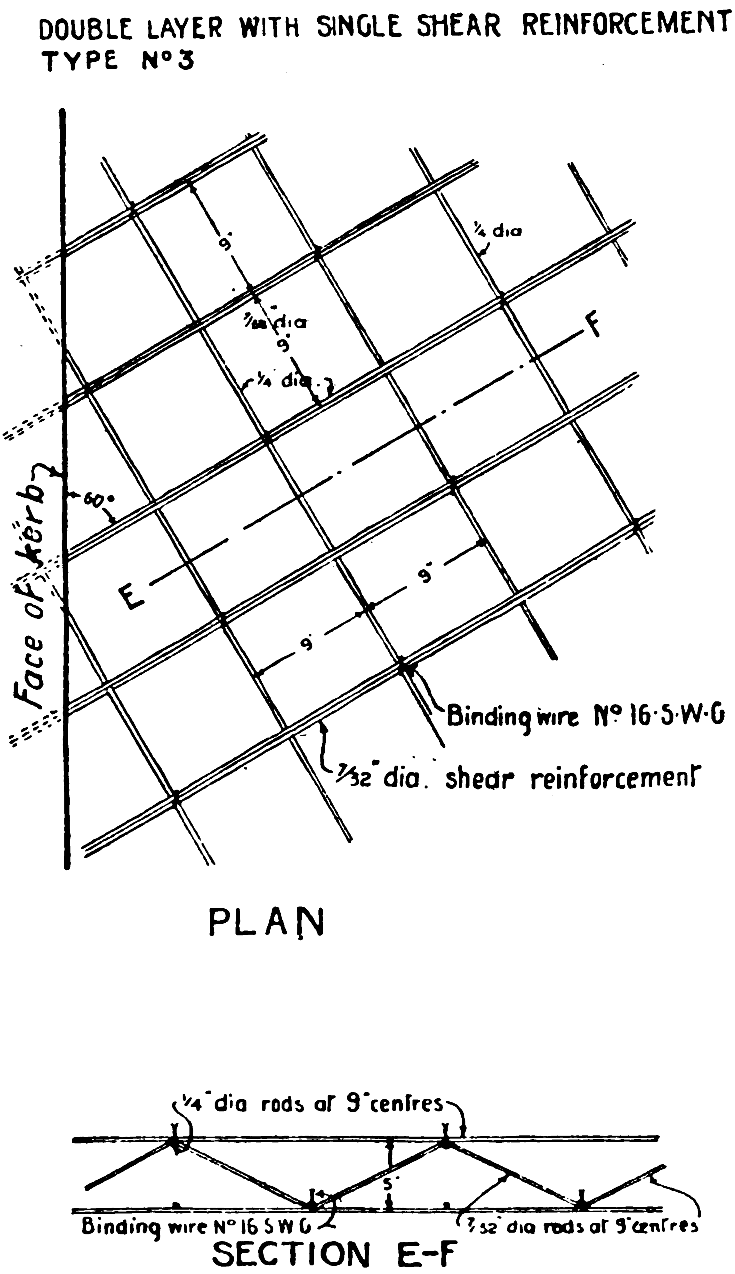


SECTION A-B

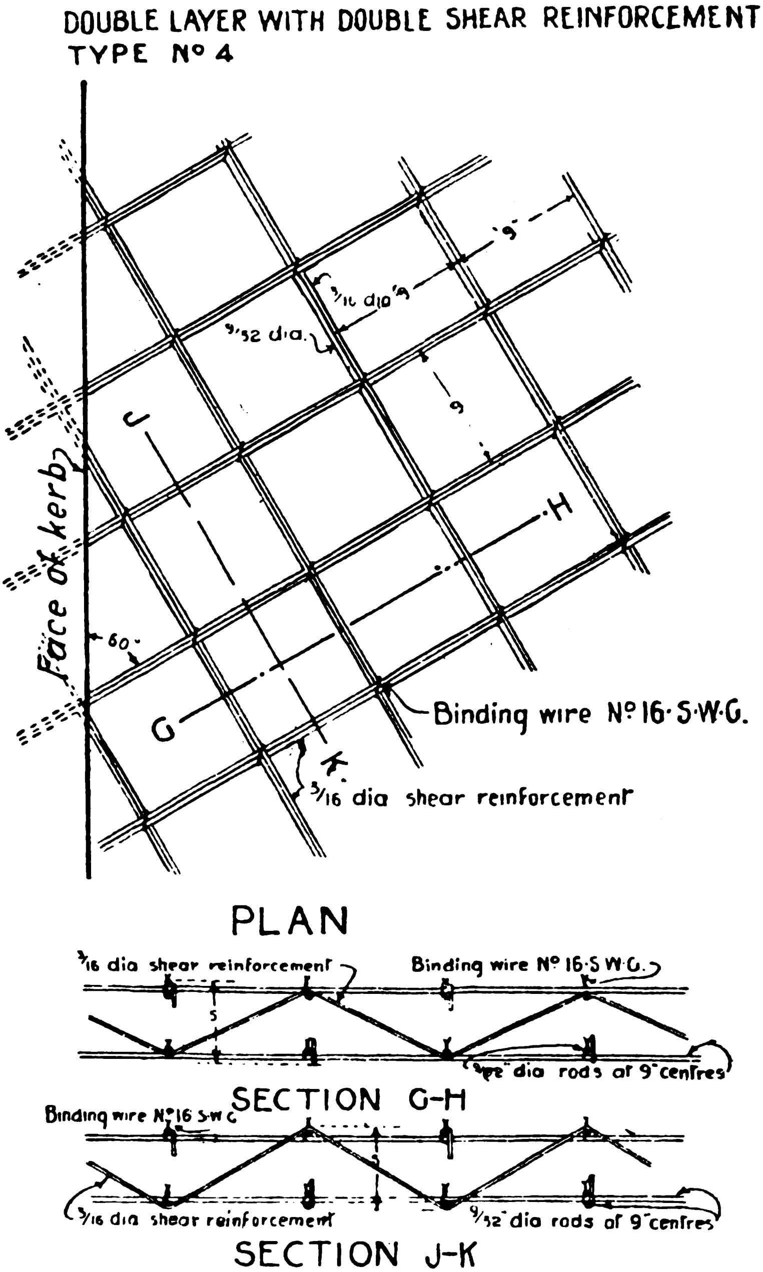
Concrete Roads in Surrey: Details of Reinforcement.



Concrete Roads in Surrey: Details of Reinforcement.


DOUBLE LAYER WITH SINGLE SHEAR REINFORCEMENT
TYPE N°3
¼ dia
7/32 dia
9"
9"
¼ dia.
F
60°
E
9"
9"
Face of kerb
Binding wire N° 16·S·W·G
7/32" dia. shear reinforcement
PLAN
¼" dia rods at 9" centres
5"
Binding wire N° 16 S W G
7/32" dia rods at 9" centres
SECTION E-F

Concrete Roads in Surrey: Details of Reinforcement.


DOUBLE LAYER WITH DOUBLE SHEAR REINFORCEMENT
TYPE No 4
Face of kerb
60°
9"
9"
5/16 dia
9/32 dia.
J
H
G
K
Binding wire No 16·S·W·G.
5/16 dia shear reinforcement
PLAN
5/16 dia shear reinforcement
Binding wire No 16·S W·G.
5
9/32" dia rods at 9" centres
SECTION G-H
Binding wire No 16 S·W·G
5
5/16 dia shear reinforcement
9/32" dia rods at 9" centres
SECTION J-K

Concrete Roads in Surrey: Details of Reinforcement.

ing uneveness in the surface on each side of the crack.

(*b*) It assists in distributing the load transmitted through the concrete to the sub-soil.

(*c*) It increases the shearing resistance of the concrete.

(*d*) It increases resiliency.

(*e*) A thinner raft of concrete may be adopted than in the case of a raft without reinforcement.

(*f*) In the event of repairs to the concrete being necessary it provides a bond between the old and the new work.

The following reasons may be submitted against the use of reinforcement:

(*a*) It increases the cost of laying the concrete by interfering with the continuity of mixing and placing and by requiring forms to hold it in position.

(*b*) It is expensive to cut in case of repairs.

(*c*) Objections are raised by gas companies on the ground that in the event of a leakage of gas under the road there is risk of ignition of escaping gas during cutting operations.

If the percentage of water which gives maximum strength to the mortar be used there is great difficulty and increased labour in securing a proper mix and surface finish. For the purpose of obtaining a satisfactory finish a slightly wetter mix can be adopted for the wearing surface than for the lower course of concrete.

Successful results have been obtained both from the continuous system and the alternate bay system of construction.

Treatment of the surface with dressings of tar, bitumen or mixtures of both these materials has not proved satisfactory, and it is doubtful whether the advantage which might be gained from such treatment is commensurate with the cost. If satisfactory materials and methods of construction are adopted, resulting in the production of a dense impervious surface, disintegration of the surface will be reduced to a minimum.

Treatment of the finished surface with silicate of soda assists in producing the hard surface required.

Concrete roads have not been the subject of complaints with regard to slipperiness and consequent skidding of vehicles.

United States.

Reports from the United States were submitted by Mr. Clifford Older, M.Am. Soc.C.E., Professor Duff A. Abrams, M.Am.Soc.C.E. (Professor in Charge, Structural Materials Research Laboratory, Lewis Institute, Chicago), and Messrs. J. Shirley Bright (District Engineer, U.S. Bureau of Public Roads), Raymond W. Coburn (Construction Engineer, State Highway Department, Boston), Charles R. Ege (Manager, Highways Bureau, Portland Cement Association), Albert T. Goldbeck (Chief, Division of Tests, United States Bureau of Public Roads), Herbert J. Kuelling (Construction Engineer, State Highway Department, Wisconsin), Robert M. Morton (State Highway Engineer, California), Frank T. Sheets (Chief Highway Engineer, Department of Public Works and Buildings, Illinois), Leroy C. Smith (Chief Engineer, Wayne County Highway Commission), and Charles M. Upham (Chief Engineer, State Highway Department, Raleigh, North Carolina).

It is obvious from these reports that the extensive construction of all-concrete roads in the United States has resulted in standardisation, and the reports were mostly confined to refinements.

Materials.—Professor Abrams dealt with the selection and testing of materials, as follows :—

Aggregates.—The aggregate in the usual concrete mixtures comprises about 75 to 85 per cent. of the materials ; consequently the characteristics of the aggregates are of considerable importance. Recent investigations have shown that the quality of the concrete as measured by its strength and resistance to wear is dependent to a large extent on the relative quantities of cement and mixing water, and to a lesser degree on the quality of the aggregate, so long as it is clean, structurally sound and properly graded.

Thorough investigation has demonstrated that the strength and resistance to wear is dependent only to a slight degree upon the weight, hardness, or toughness of the coarse aggregate, so long as the compressive strength of the material is not lower than the concrete. Other tests have shown that concrete made from limestones, gravels, traps, sandstones and blast-furnace slags as coarse aggregates give essentially the same strength so long as the grading is similar and the quantity of water absorbed by the aggregate is taken into account in proportioning the batch.

Experience has shown that rocks which give comparatively high loss in abrasion tests are satisfactory for the wearing surface of concrete roads. The softer limestones, and in some cases sandstones, have given excellent results. In sections of the country where coarse aggregates are scarce, sand only has been used as aggregate in concrete roads with satisfactory results; where there is little danger from freezing and thawing, sea shells are sometimes used.

The reason for steady lowering in the requirements as to hardness of aggregates for concrete roads during the past few years is partly due to the change in traffic. Rubber-tyred vehicles produce little or no surface wear on a properly constructed concrete road. Horse-drawn and steel-tyred vehicles have practically disappeared except for certain city streets.

The strength and durability of concrete depend largely on the quality of the cement and to only a minor degree on the characteristics of the aggregates. In other words, if proper methods of placing and curing are employed, concrete of acceptable quality can be produced from aggregates which are generally considered inferior; on the other hand, poor concrete may result from the use of constituent materials of the highest quality if proper methods are neglected. Care to avoid an excess of mixing water and proper provisions for curing are the most important factors in producing durable concrete.

Water for Mixing.—Extensive tests on the compressive strength of Portland cement have been made, using mixing waters of a wide range of types, many of which were thought to be unsuitable for concrete. In spite of the wide range in the quality of the waters used, and contrary to previously accepted opinion, most of the impure waters gave good results in concrete, apparently due to the small quantity of injurious matter present. The quality of a water for mixing concrete is best measured by the ratio of its 28-day concrete or mortar strength to that of similar mixes made with pure water. Waters which give strengths less than 80 per cent. of those obtained with pure water should be considered unsatisfactory. The odour or colour of water are not safe indications of quality. Water which is suitable for drinking can be used without question. The important point is not whether impurities are present, but do the impurities occur in injurious quantities?

Accuracy of Construction.—Mr. J. Shirley Bright said American highway engineers ensure accuracy of construction by the use of substantial rigid forms of steel, machinery for all major operations, and close inspection supported by numerous instrumental observations.

Forms.—The forms must have ample section to carry a heavy template or finishing machine without deflection. They are set on thoroughly compacted subgrade or on stakes spaced not over 5 ft. apart and held in alignment by steel pins.

Subgrade.—Preparation of the subgrade is now directed toward uniformity rather than a high degree of compaction. Subgrade is checked by scratch template just prior to pouring concrete. This template is generally built of steel channels placed back to back, with a timber liner between. The liner contains on its lower side adjustable steel teeth, making it adaptable to different sections. This template is fastened to a 4-wheel carriage of proper gauge to ride the forms. The template, rolling back and forth, marks by depth of groove the exact material above subgrade to be removed.

Transverse Contour.—The accuracy of the transverse contour depends both upon the efficiency of the equipment and the skill of the operators. The finishing machines are used on all sections except widened curves. These machines mechanically operate a belt and two strike boards, and produce excellent results when handled by skilful operators. The screed is still used on sharp widened curves, and is sometimes followed by a roller. A longitudinal float should be used to remove transverse waves. This float should consist of a board not less than 16 ft. long and 8 in. wide, ending in suitable handles. It is operated by two men from bridges spanning the road. The final finishing is produced by belting.

Joints.—Trueness of surface across the joints is produced by the use of split floats or roller. Its smoothness should be tested by a notched straight-edge. Specially designed straight-edges of aluminium are being manufactured for use of inspectors, and are very convenient.

Final Check of Surface.—The surface is finally checked for slight variations by the use of a 10-ft. straight-edge. This is handled from a bridge while the concrete is still workable. The 10-ft. straightedge is again used upon the surface after the concrete is set, and any irregularities beyond the tolerance of the specifications are removed by carborundum stone.

Reinforcing Steel.—Reinforcing steel is generally used in the form of bars or welded wire sections. The concrete is poured in two layers ; the lower is roughly struck off at the required thickness and the steel laid directly thereon. The upper layer is poured immediately and not allowed to lag more than fifteen minutes behind the pouring of the lower layer. The concrete may be poured in one layer if bars are used for reinforcement, but steel chairs or skids are then required to support the steel. The skids are attached to and move forward with the mixer.

Smoothness.—Some States, before acceptance of the contract, test the smoothness of the entire surface by using the profileometer or vialog. These automatically plot a profile of the surface irregularities. The profileometer has been developed by the Illinois State Highway Department and consists of an automatic registration device supported on 32 bicycle wheels. The vialog originated in the New York Highway Department and can be attached to the dash of any motor car. A clutch is provided, allowing the instrument to be operated on sections where desired. An eleven-mile section can be plotted without the necessity of replacing the paper.

Thickness.—The thickness of the roadway is checked by drilling cores, or by level readings. Benches are established on either side of the road at typical stations, and from these points, with either a Wye level or a string stretched over both bench marks, comparative readings are taken on the subgrade and finished surface. When resort is had to cores, they are taken at 1,000 ft. intervals, and more frequently if the sections show irregularity.

Expansion Joints and Surface Smoothness.—Mr. H. J. Kuelling, dealing with expansion points, said theory showed that concrete expands, and the first conclusion would be that we surely need transverse expansion joints. However, practical experience largely disagrees with this theory and shows otherwise. Economy is a strict taskmaster. Anything that adds unnecessarily to the ultimate cost is not justifiable. This subject was discussed with engineers of eight States doing a considerable amount of concrete paving, and of the eight, only one is putting in transverse expansion joints as a standard practice. Some have used them in the past and abandoned their use and some have never used them. In these States there are probably 10,000 to 12,000 miles of concrete roads without expansion joints.

Some of the objections offered by these practical engineers are as follows : The difficulty of getting a smooth riding surface where the joints are installed. They contend that the joints do not prevent " blow-ups." That, as a matter of fact, they have more " blow-ups " on the roads with joints than they do on those without. This is due to faulty construction at the joint. There is also a very great tendency for one slab to rise on another due to the greasing action of the material in the joint filler, especially when the joint is not exactly perpendicular to the face of the concrete. They maintain that the filler in joints squeezes out and is eventually replaced by dirt, so that in time they have the same effect as no joint.

It is, on the other hand, common practice in several of these States to place 1 in. expansion joints from 30 ft. to 50 ft. on each side of all bridges.

It is also common practice at a construction joint to lock one slab to the other with dowels free on one end, or by tongue and groove method. One State is anticipating the location of transverse cracks by placing a steel plate, similar to that used in longitudinal joints, at varying intervals across the road. At present they are placing them 36 ft. 6 in. apart. This practice has been in vogue for over a year, and they seem quite well satisfied with the results.

There is a very growing demand for smoother and, therefore, better riding pavements. A common practice is to require not over ¼ in. deviation in 10 ft. although some are seeking an even finer finish. Lack of consistency of mix is apparently one of the most important causes of rough pavements. This does not merely mean the differences as shown by slump tests, but goes back even farther to getting the same amount of fine aggregate with a certain amount of water. This necessitates at least the weighing of all aggregates and correcting for the moisture content, or better still measuring them by some such method as inundation, in which case the correct amount of both fine aggregate and water is guaranteed. A uniform condition of the subgrade will add more certainty to uniform consistency of concrete.

Surface smoothness naturally cannot be obtained without the use of good substantial side forms which have been thoroughly bedded and fastened in place. With well placed forms and uniform consistency in the concrete, the obtaining of a smooth surface becomes a matter of workmanship. First of all, the form must be kept clean ahead of any strike-board or screed, be it mechanical or hand manipulated. Concrete must be tamped, not too hard or too much, but uniformly over the entire surface. The surface should be struck off several times and tested with a straight-edge. The last straight-edging can well be done the day following the placing of the concrete and any inequalities corrected at that time with a carborundum brick and water. Surplus water and laitance may be removed either by hand rollers or wooden floats.

The longitudinal float is rapidly coming into use, and with uniformity in all conditions, especially in the consistency at the time of using the float, will improve the riding qualities. It should be remembered that concrete with a uniform consistency can be made non-uniform by variation in the amount of tamping and rolling.

Surface smoothness will result only when there is uniform subgrade, uniform consistency, uniform side forms, uniform tamping and uniform finishing.

Curing.—In discussing the subject of curing, Mr. L. C. Smith said, for the long life of a concrete road, curing is one of the most important operations in connection with its construction.

Promptly (not longer than 30 minutes) after the final finish of the concrete surface of the road, 12-ounce or heavier burlap should be placed on the green concrete. This covering is kept damp by spraying lightly with water. Convenient size for the burlap strips is 6 ft. wide and 4 ft. longer than the width of the roadway. Canvas shades should be provided to protect the concrete immediately after pouring and finishing in hot weather, in case of rain, or especially in arid climates.

Twenty-four hours after the application of the burlap it is removed and one of the following methods of covering or curing is adopted. (1) Calcium chloride application, (2) ponding, (3) spraying, (4) earth cover.

To cure with calcium chloride, the flake is sprinkled on the surface of the concrete in dry form. It absorbs moisture from the air to keep the pavement damp until final set has been accomplished. Two pounds of calcium chloride are used per sq. yd. This method is still in the experimental stage, but seems practical where earth covering or water or both are not available in the proper quantities.

To cure by ponding, earth dykes are prepared along the edge of the pavement and about every 25 ft. transversely. Spaces so formed are filled with water, thereby forming ponds. These must be kept filled for 10 or 14 days, after which the dykes are removed and the concrete allowed to dry out. At the end of three weeks the road may be opened to light traffic with pneumatic tyres, and in four weeks to all traffic. This method is desirable where earth covering is scarce and water is plentiful. It is economical because only a small amount of earth has to be handled.

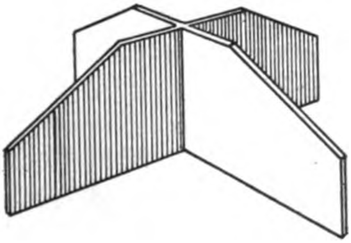
To cure by spraying, a system of pipes must be installed to supply sprayers with ample water. Spraying is to be continued until the expiration of 10 or 14 days. Provision must be made to lead excess water to the side ditches. This method produces excellent results but causes extravagant use of water.

To cure with earth cover, after the burlap is removed 2 in. or more of earth should immediately follow. The edges of the concrete should be covered also. The earth should be loamy, sods preferred. Never use light sand. This cover is sprayed or sprinkled for 10 days following laying. Sufficient water must be used to keep the covering damp at all times. If a concrete mixer is producing 400 or 500 ft. of 18 or 20 ft. road a day, 3 men should be assigned to sprinkling. Ample water line must be provided to supply mixer and sprinklers at the same time. This should be not less than 2 in. pipe. This method is the most common and probably the most economical. At the end of 10 days sprinkling is suspended, and at the end of 2 weeks the earth covering is removed, allowing the concrete to dry out. Light pneumatic-tyred traffic may safely use the road at the end of 3 weeks, and all traffic may be permitted in 4 weeks.

It is considered good practice to allow traffic to cross over new roads at important intersections when the roads are 10 days old. At these points protection is had by planking and heavily covering the new concrete. Ninety per cent. of all American roads are cured by the earth-covering method. Many engineers are permitting contractors to neglect covering. Sometimes the earth is put on and sprinkling is omitted.

Sweden.

Device for measuring Surface Wear.—All concrete roads in Sweden closely follow general practice. In his report, however, Mr. Wretland describes a device invented by Mr. S. Ekeland, of the Swedish Institute of Roads, for measuring the wear of concrete road surfaces. This consists of two thin lead plates fixed crosswise as illustrated. The device is inserted in the road so that the top edge is flush with the surface. The horizontal top edges have a total length of about 4 in., and then slope downward to form slopes of 1 in 2. The amount of the wear is measured by the lengthening of the tops of the plates. Thus if, after wear, the top is found to measure 4½ in., an increase of ½ in., the amount of wear is ¼ in.



Device for Determining Wear of Road Surface.

Denmark.

Thin Slabs.—Mr. S. Ellert stated that in Denmark they are laying concrete surfaces direct on existing macadam roads, and that by this means a reinforced concrete slab of 4 in. only is found sufficient to carry main-road traffic of 1,000 tons per day. The existing macadam surface is carefully shaped to crossfall and levelled, and it is claimed that by using this as the bed for the concrete cracks are minimised both by the absence of any movement of the sub-soil as might be present on a newly-rolled bed, and by the decrease in the movement-friction between the concrete and the bed when the former expands and contracts under temperature changes. These roads are laid in half widths without transverse expansion joints. Square mesh reinforcement is used in the centre of the slab. Steel rods, ⅜ in. in diameter, are laid across the longitudinal joint at 4ft. intervals. The mix is 1 : 2 : 3, the coarse aggregate not exceeding ¾ in. It is stated that roads of this type laid in 1923 are standing the traffic well.

Belgium.

Road-making with Cement Gun.—An experiment in the use of the cement gun for road construction is described in the report of MM. Piers and Luyssen. By this method a layer of cement and sand was laid on an existing macadam road to a depth of about 1½ in. The macadam was scarified and then rerolled without binding material, and on this surface the grout was projected by the gun. The macadam is first well cleansed by the application of a jet of water under pressure. The first layers of grout are of a very thin consistency so as to enter into and bind the macadam, while in the upper layers the quantity of water is reduced so that the grout will lie where it is placed and not flow in the direction of the camber of the road. Surfacing is carried out in the same way as with other methods of concrete laying.

According to the authors of the report this experiment was not a complete success, not through any fault of the cement gun, but because of lack of experience in its use for this class of work. The chief trouble appears to have been the very rapid formation of potholes, some of which were noted within 24 hours of the traffic using the road. This is attributed to the different consistencies of grout used for the different layers; the lower layers contained the greater proportion of water, and in places where the existing macadam was most absorbent the layers applied first were practically entirely absorbed leaving hollow spaces beneath the drier upper layers.

Accident Prevention in Building Operations.

THE new Home Office regulations for Building Works which come into force on October 1, 1926, have now been issued. These regulations (London: H.M. Stationery Office. Price 3*d*.) will apply to all premises on which machinery worked by steam, water, or other mechanical power is temporarily used for the purpose of the construction of a building, or for the purpose of any addition to the structure of an existing building.

The Regulations are as follows:

Part I.—Duties of Employers.

1. Suitable scaffolding plant shall be provided for workmen where necessary. All scaffolding and appliances connected therewith shall be of sound material and of adequate substance having regard to the purpose for which it is to be used. The parts thereof shall be examined before use as to strength and suitability, and if found defective, shall be repaired; or if not capable of repair, shall not be used as scaffold plant.

2. Sufficient material shall be provided for, and shall be used in the construction of, scaffolds, and when in place shall not be removed until the part to be removed is no longer required for working purposes, stability, or safety.

3. Pole standards and the legs of gabbard scaffolds shall be vertical and fixed sufficiently close together to secure the stability of the scaffolding having regard to all the circumstances of the case; the ledgers shall be practically level, and the whole scaffold shall be sufficiently and properly braced. Gabbard scaffolds, frames, standards, or other appliances used as supports for working platforms shall be of sound construction, shall have a firm footing and shall be adequately secured, strutted and braced. The legs and needles of gabbard scaffolds shall be securely fastened together by bolts, dogs, clamps, or other effective means.

4. Every working platform which is more than 5 ft. above the ground or floor—

(*a*) shall be closely boarded or planked, provided that a space not exceeding 3 in. may be left between any two boards or planks of a platform used only by plasterers or painters;

(*b*) (i) shall be at least 17 in. wide if used as a footing only and not for the deposit of any material;

(ii) shall be at least 34 in. wide if used for the deposit of material;

(iii) shall be at least 43 in. wide if used for the support of any higher platform:

Provided that a working platform upon which stone is dressed or roughly shaped shall be at least 51 in. wide and, if used for the support of any higher platform, shall be at least 60 in. wide.

(*c*) shall, if part of a pole or gabbard scaffold, be at least 42 in. below the top of the standards wherever possible.

Provided that this Regulation shall not apply to a working platform which is on the outside of a roof.

Provided also that a width of at least 10½ in. shall be sufficient for a working platform used for glazing a roof if the said platform is bolted or otherwise firmly fixed at one end to a bracket securely hooked to a purlin and rests securely at the other end on another purlin.

5. Every working platform erected on trestles, other than folding trestles, shall, where the trestles are of less height than 5 ft., be 34 in. wide, except that a width of 17 in. shall be sufficient in the case of a platform primarily used as a footing only and not used for the deposit of any material.

6. No trestle scaffold of more than three tiers or exceeding a height of 15 ft. from the ground or floor shall be used.

7. Every board or plank forming part of a working platform or run shall be supported at proper distances and near each end by a putlog or other support, and no such board or plank shall project beyond its end support to a distance exceeding four times the thickness of the board or plank.

8. Where there is a space between a wall and a platform used for plastering the wall, this space shall not exceed 18 in. in breadth.

9. (*a*) Boards or planks which exceed 1½ in. in thickness and form part of a working platform or run shall not overlap each

other. Provided that this Regulation shall not apply to any platform or run supported by trestles or by a gabbard scaffold if steps, such as the provision of bevelled pieces, are taken to reduce to a minimum the risk of tripping.

(*b*) Boards or planks which form part of a run mainly used for the movement of barrows shall not overlap each other unless steps, such as the provision of bevelled pieces, are taken to facilitate the movement of the barrows.

10. Every gangway or run shall be at least 17 in. wide when any part is more than 5 ft. above the ground or floor except a gangway or run leading to a plasterer's scaffolding in the interior of a room or place in which the height from the floor to the ceiling does not exceed 14 ft. All planks forming a gangway or run shall be so fixed and supported as will prevent undue or unequal sagging. when the slope renders additional foothold necessary, proper stepping laths the full width of the gangway shall be provided at suitable intervals not exceeding 2 ft.

Provided that this Regulation shall not apply to any run which is of a width of at least 11 in. and is of adequate thickness and is mainly used for the movement of barrows unless—

(*a*) the said run reaches a height of more than 5 ft. above the ground, or unless

(*b*) the said run is placed over an excavation which is more than 7 ft. deep and 10 ft. across.

11. No working platform, run or gangway more than 2 ft. above the ground or floor shall be supported by loose bricks, drain pipes, chimney pots or other unsuitable material.

12. No working platform, gangway or run shall be used for working upon until its construction is completed and the safeguards required by these Regulations properly fixed.

13. Where a scaffold has not been erected by or under the superintendence of the employer whose workmen are to use it, the said employer, before allowing work to proceed thereon, and during such period as any person employed by him is engaged thereon, shall satisfy himself, either personally or by his agent, that the scaffolding is in a stable condition, and that the materials used in its construction are sound, and that the required safeguards are in position. During the usage of the scaffolding due regard shall be paid to its carrying capacity.

14. Scaffolding in use shall be examined once a month by a competent person deputed by the employer responsible for the scaffolding, who shall within three days of his examination make an entry in the prescribed register, to the effect that he has examined the scaffolding and its fittings and connections, and showing the prescribed particulars of the result of his examination. The register shall be kept on the premises to which the Regulations apply.

15. Every working-place and approach thereto shall be efficiently lighted.

16. Every gangway and staircase shall be kept free from any unnecessary obstruction, and if over 12 ft. from the ground or floor, shall be provided with a suitable handrail or other efficient means to prevent the fall of persons, except where and when access is required for workmen or for the movement of material.

Provided that this Regulation shall not apply to a temporary gangway used only in connection with glazing or with the erection of ironwork or steelwork.

17. Every working platform which is supported by trestles and is more than 14 ft. from the ground, gantry, or floor, and every working platform which is otherwise supported and is more than 12 ft. above the ground, gantry, or floor, shall, where practicable and while in actual use, be provided on the side away from the wall and at each end with a suitable guard rail and toe-board or with other efficient means to prevent the fall of persons or articles from the platform, except where and when access is required for workmen or for the movement of material.

Provided that this Regulation shall not apply to a working platform which is on the outside of a roof, nor to a working platform which is used only by glaziers or by riveters or bolters-up in ironwork or steelwork.

Provided also that a toe-board shall not be required on a working platform used only by plasterers or painters.

18. Every pole used for scaffolding shall have the bark stripped off.

19. At least one-third of the putlogs used for supporting any working platform more than 12 ft. above the ground or floor shall remain in position until the scaffolding is finally removed, and one-half of the

number so remaining shall be securely fastened.

20. Every employer shall post notices on premises to which these Regulations apply stating that no pole, plank, chain, rope or other material shall be thrown from a scaffold, floor, window, or other opening over 20 ft. above the ground, but shall be properly lowered.

21. No person shall be employed on the outside of any roof which has a pitch of over 34 degrees, unless a parapet wall, railings, an outside working platform or other efficient means are maintained to prevent the said person from falling from the edge of the roof.

Provided that this Regulation shall not apply to :—

(*a*) a roof the eaves of which are less than 22 ft. above the ground, or to

(*b*) a person employed in the erection of any ironwork or steelwork other than roof covering.

22. No person shall be employed on extensive work on the outside of any roof which has a pitch of over 34 degrees unless the following facilities are provided thereon :—

(*a*) a suitable working platform, securely supported and of a width of not less than 8½ in., and

(*b*) suitable and sufficient ladders, duck ladders, or crawling boards, properly secured.

Provided that this Regulation shall not apply to a person employed in the erection of ironwork or steelwork.

23. No scaffold shall be supported by a cast-iron eaves gutter.

24. Cantilever or jib scaffolding shall be constructed of materials of adequate strength, securely fixed and anchored from the inside, and of sufficient length to ensure stability and shall also be properly braced and supported.

25. When bedding window frames a platform shall be provided to enable workmen to perform their task without danger to themselves or those below them.

26. No suspended scaffold shall be used unless it complies with the following requirements :—

(*a*) The platform shall be at least 17 in. wide and of adequate strength.

(*b*) The means of suspension shall be of adequate strength firmly secured. If a weight is used for the purpose of suspension, this weight shall be adequate having regard to all the circumstances of the case.

(*c*) The scaffold shall be provided with a suitable guard rail and toe-board, or other efficient means to prevent the fall of persons or articles from the platform.

Trestles or other means of increasing the height of the working platform shall not be used on suspended scaffolds.

When a skip or large basket is used as a suspended scaffold for one man, it shall not be less than 2 ft. 6 in. deep, and shall be carried by two strong iron bands properly fastened and continued round sides and bottom, with eyes in the iron to receive the ropes.

27. No working platform resting on wooden bearers let into the wall at one end and without other support shall be used unless the bearers go right through the wall, are securely fastened, and are of sufficient strength.

No figure or bracket scaffold supported or held by dogs or spikes driven into the wall shall be used.

28. Planks supported by ladders, steps, or folding trestles, shall be of adequate width and thickness. Where steps are used, the platform shall not exceed 7 ft. in height.

29. Every ladder used as a means of communication shall rise at least 5 ft. above the place of landing, shall not stand on loose bricks or other loose packing, but shall have a level and firm footing, and shall be securely fixed so that it cannot move from its top point of rest ; undue sagging shall be prevented. Every ladder which cannot be secured at the top, shall, if over 25 ft. in length, have a man stationed at the foot to prevent slipping, or shall be securely fastened at the base. A ladder having a missing or defective rung shall not be used.

No ladder made of sawn timber shall be used unless of adequate strength and the steps securely notched in or housed.

30. Every opening left in a floor of a building or in a working platform for an elevator shaft or stairway, or for the hoisting of material, or for access by workmen, or for any other purpose, shall, until it becomes necessary to remove the fencing in order to complete the permanent enclosure, be provided with a suitable

guard rail and toe-board or with other efficient means to prevent the fall of persons or articles into the opening, except where and when access is required for workmen or for the movement of material.

31. Any part of the premises in which any person is habitually employed shall be covered in such a manner as to protect any person who is working in that part from being struck by any falling material or article.

32. The stage for every crane shall be built of sound material, shall be of good mechanical construction having regard to its height and the lifting and reaching capacity of the crane. The crane shall be securely anchored or weighted. The platforms for the driver and signalman shall be of sufficient area, close-planked, securely fenced, and provided with safe means of access.

33. On every stage, gantry or other place on which a crane moves an unobstructed passageway of at least 2 ft. in width shall be maintained at every position of the crane between the cab or any other part of the crane and the edge of such stage, gantry or place, and between the cab or any other part of the crane and any steelwork or other material placed near the crane rails.

34. The working gear and anchoring appliances of every crane, crab or winch and other hoisting apparatus shall be kept in good repair and in good working order, and shall, as far as practicable, be examined in position at least once in every week by a competent person. The results of this examination shall be entered forthwith in the prescribed register. Every hoisting rope or chain shall be securely fastened to the barrel of the crane, crab or winch with which it is used.

35. Every crane, crab, and winch shall be provided with an efficient brake or brakes and shall have the safe working load plainly marked upon it. If the safe working load of a crane may be varied by the raising or lowering of the jib or otherwise an automatic indicator of the safe working loads, or a table showing the safe working loads at the corresponding inclinations of the jib, shall be attached to the crane.

The lever controlling the link-motion reversing gear of every steam crane shall be provided with a suitable spring-locking arrangement.

Every hoisting machine, and all tackle or apparatus and all appliances connected therewith, shall be of good mechanical construction, sound material, and of adequate substance, and shall be properly and securely fixed and of suitable strength.

No rope shall be used over a pulley block if its diameter exceeds the diameter of the grooves of the block.

36. No crane or gear shall be loaded beyond the safe load. No load shall be left suspended from a crane unless there is a competent person actually in charge whilst the load is so suspended.

37. Every chain used on the premises for hoisting or lowering shall—

(*a*) have been tested ;

(*b*) be inspected by the foreman or other responsible person immediately before each occasion on which it is used in hoisting or lowering unless it has been so inspected within the preceding three months ;

(*c*) if in general use, be annealed once at least in every 14 months unless it has been subjected to such other heat treatment as the Secretary of State may sanction ; and

(*d*) shall be legibly marked in plain figures and letters with an identifying number or description and with the safe working load of the chain.

The prescribed particulars of every such chain shall be entered into or attached to a register which shall be kept on the premises or at the head office of the employer of the person or persons using the chain. This register shall at all reasonable times be open to inspection by an Inspector, and the employer shall send to an Inspector such extracts therefrom as the Inspector may from time to time require.

38. Every crane driver shall be properly qualified. No person under 18 years of age shall be employed to give signals to a crane driver.

39. When any hoisting or lowering is performed by means of a crane which is in such a position that the crane driver is unable to see the load in all its positions, a look-out man shall be employed to give the necessary signals to the driver.

40. Every signal for hoisting or lowering shall be such as can be readily heard or seen, and shall be distinctive in its

meaning to the person who has to act upon it. Where a sound signal is used, the signal shall be made by an efficient gong, whistle, or electric apparatus, or other efficient means. Every signal wire shall be protected from accidental interference.

41. Every box used for hoisting bricks or other loose material shall be closed in except on one side. One or more of the sides may be hinged or securely slotted.

42. Every hook used for hoisting or lowering shall either be provided with an efficient spring catch to prevent the displacement of the sling from the hook or shall be of such a shape as to reduce as far as possible the risk of such displacement.

43. No basket depending entirely for support on its handles shall be used for hoisting or lowering.

In hoisting a barrow, the wheel shall not be used as a means of support unless efficient steps are taken to prevent the axle from slipping through the bearing.

44. All rails on which a travelling crane moves shall be of uniform section, shall be secured by fishplates, and shall be securely fastened to sleepers.

Provided that this Regulation shall not apply to an overhead crane on bridge rails.

45. The flywheel of every engine, all dangerous parts of the machinery, and every part of the mill-gearing shall be securely fenced, or be in such a position or of such construction as to be equally safe to every person employed as they would be if they were securely fenced. Every water-gauge glass on a steam boiler shall be adequately protected by a guard. All electrical apparatus and electrical conductors shall be so installed and protected as to prevent danger to any person employed.

46. When necessary, in all excavations, timber struts, waling planks, and boards shall be provided and used; and in works of underpinning the adjacent walls and ground shall be properly shored and strutted if necessary.

47. There shall be provided in a readily accessible position or positions a sufficient number of "First Aid" boxes or cupboards. Each such box or cupboard shall contain such materials and equipment as may be prescribed,* shall be distinctively marked, and if newly provided after the date on which these Regulations come into force shall be plainly marked with a white cross on a red ground.

48. No ironwork or steelwork on which there is wet paint shall be handled on the premises. Provided that this Regulation shall not apply to the painting of ironwork or steelwork on the premises.

Part II.—Duties of Workmen.

49. Every person employed shall cooperate with the employers in carrying out Part I of these Regulations, and shall report to the employer or foreman any defect he may discover in the plant or appliances.

50. No person employed shall interfere with, take away, or destroy any of the plant or safeguards required by these Regulations without the authority of the employer or his responsible foreman.

51. No person employed shall be lifted or carried by a crane (except on the driver's platform) or ride in a barrow hoist, or in a hod hoist, or adopt other unsafe means of getting about the building, but every such person shall use the gangway ladders, or staircases or other safe means provided for the purpose.

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* The following standard has been prescribed by the Secretary of State under this regulation.

Each first-aid box or cupboard shall contain at least:

(1) A copy of the first-aid leaflet (Form 923) issued by the Factory Department of the Home Office.
(2) A sufficient number (not less than two dozen) of small sterilised dressings for injured fingers.
(3) A sufficient number (not less than one dozen) of medium size sterilised dressings for injured hands or feet.
(4) A sufficient number (not less than one dozen) of large sterilised dressings for other injured parts.
(5) A sufficient number of sterilised burn dressings (small and large).
(6) A sufficient supply of sterilised cotton wool, in $\frac{1}{2}$-oz. packets.
(7) A two per cent. alcoholic solution of iodine.
(8) A bottle of sal volatile, having the dose and mode of administration indicated on the label.
(9) Eye drops, prepared as described in the first-aid leaflet (Form 923).
(10) A supply of suitable splints and cotton wool or other material for padding.
(11) A supply of adhesive plaster.
(12) A tourniquet.
(13) One dozen roller bandages.
(14) Half a dozen triangular bandages.
(15) Safety pins.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	,,	14	0
,, ,, ½ in. mesh	,,	15	6
Thames ballast	,,	10	6
Broken brick (¾ in.)	,,	11	6
Best British Portland Cement	per ton 58*s.* to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10*s.* per ton extra		
"Super-Cement"	per ton 88*s.* to	93	0
"Lightning" Brand Aluminous Cement	,, 100*s.* to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	d.	*Wrot.* s.	d.
1 in.	per square	23	6	27	6
1¼ in.	,,	29	6	33	6
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	,, £20 ,, ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2¼ in. Rounds	per cwt.	10	6
7/16 in. to ½ in. Rounds	,,	10	9
⅜ in. Rounds	,,	11	0
¼ in. Rounds	,,	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per foot cube	1	11
Do.	do.	in columns	,, ,,	2	1
Do.	do.	in beams	,, ,,	2	3
Do.	do.	in floor slabs 4 in. thick	per yard super	6	0
Do.	do.	in floor slabs 5 in. thick	,, ,,	7	6
Do.	do.	in floor slabs 6 in. thick	,, ,,	9	0
Do.	do.	in floor slabs 7 in. thick	,, ,,	10	6
Do.	do.	in walls 6 in. thick	,, ,,	8	8

(Add for hoisting 3s. 6d. per yard cube above ground-floor level. Add for "Ferrocrete" 1s. 10d. per yard cube.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
,, 7/16 in. to ½ in.	,,	21	6
,, ⅝ in. to 2¼ in.	,,	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	,, ,,	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	,, ,,	1	1½
Do. do. as last, in narrow widths	,, ,,	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	,, ,,	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

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Prospective New Concrete Work.

Aberystwyth. — *Promenade.* — The T.C. is considering a scheme for extending the promenade from Constitutional Hill to Clarach Bay.

Bangor.—*Houses.*—The T.C. proposes to spend £45,000 on the construction of 64 houses.

Barnes (London).—*Concrete Houses.*—The L.C.C. proposes to build 657 concrete houses on the Castelnau estate at Barnes.

Barnsley.—*Houses.*—The T.C. is negotiating for a site on which to erect 150 houses.

Batley.—*Streets.*—The T.C. has applied for permission to borrow £3,350 for the construction of streets on the housing estate at Laurel Drive.

Beighton.—*Houses.*—The Chesterfield R.D.C. proposes to build 27 houses at Beighton.

Bolton.—*Houses.*—The Corporation has purchased land on which to erect 420 houses.

Brynamman.—*Road.*—A road is to be constructed from Brynamman to Cymllyn.

Cardiff.—*Houses.*—The T.C. has applied for sanction to erect 108 houses.

Carmarthen.—*Bridge.*—The Carmarthenshire C.C. proposes to spend £40,000 on the construction of a bridge at Carmarthen.

Clarkston.—*Road.*—A road is to be constructed at Cartsbridge, near Clarkston.

Corris.—*Concrete Road.*—A concrete road is to be constructed from Corris to the top of the Bwlch, Dinas Mawddwy. The cost is estimated at £50,500.

Creagan.—*Bridge.*—The Argyllshire C.C. proposes to spend £7,600 on the construction of a bridge at Creagan.

Crompton.—*Houses.*—The R.D.C. has applied for sanction to borrow £44,900 for housing purposes.

Crow Park.—*Bridges.*—The Notts. C.C. proposes to erect bridges at Crow Park, Barnby Dun, and North Muskham.

Crowle.—*Houses.*—The U.D.C. is considering a scheme for the erection of 40 houses.

Desborough.—*Road.*—The Surveyor has been instructed to prepare plans for the construction of a road to run parallel with Alexandria Road.

Downpatrick, Ireland.—*Houses.*—The R.D.C. proposes to spend £49,000 on the construction of 127 houses.

Dundee.—*Road.*—The T.C. proposes to spend £70,000 on the construction of a road from Dock Street to Ferry Road.

Eastbourne.—*Concrete Houses.*—The Corporation has received permission to borrow £56,126 for the erection of concrete houses.

Eastbourne. — *Groynes.* — The T.C. proposes to construct groynes at Langney Point.

Eton.—*Houses.*—The U.D.C. proposes to build 40 houses at a cost of £29,137.

Foryd.—*Bridge.*—The Denbighshire C.C. and the Flintshire C.C. have applied for sanction to erect a bridge across the river at Foryd.

Frimley.—*Houses.*—The U.D.C. is seeking permission to borrow £100,000 for housing purposes.

Gorebridge.—*Houses.*—The Midlothian C.C. proposes to build 52 houses at Gorebridge.

Halesworth. — *Footbridge.* — The U.D.C. is negotiating with the L. & N.E. Railway Co. with a view to constructing a footbridge over the level crossing at the railway station.

Harrogate.—*Houses.*—The T.C. has prepared a scheme for the erection of 46 houses.

Hartley Witney. — *Houses.* — The R.D.C. proposes to build 106 houses among the various parishes.

Horsforth. — *Houses.* — The U.D.C. has applied for sanction to borrow £48,500 for the erection of 100 houses.

Horsham.—*Bridge.*—The Surveyor has been instructed to prepare plans for the construction of a bridge in Blackbridge Lane. The cost is estimated at £575.

Houghton-le-Spring. — *Houses.* — The U.D.C. has applied for sanction to erect 60 houses.

Huddersfield.—*Houses.*—The T.C. is seeking permission to erect 30 houses on the Quarmby site.

Hunstanton. — *Bathing Pool.* — The U.D.C. proposes to spend £10,000 on the construction of a bathing pool.

Lagganmore.—*Bridge.*—A bridge is to be constructed at Lagganmore. The cost is estimated at £6,100.

Leicester. — *Concrete Bridge.* — The T.C. has decided to erect a reinforced concrete bridge over the river Soar at Grundon Street. The cost is estimated at £4,450.

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CONCRETE
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OIL

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FUNCTIONS BEST

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Lyme Regis.—A road is to be constructed from Lyme Regis to Charmouth. The cost is estimated at £23,102.

Marple.—*Bridge.*—The Cheshire C.C. is considering a scheme for the erection of a bridge over the River Goyt.

Monkwearmouth. — *Houses.* — The Borough Surveyor has been instructed to prepare a scheme for the erection of 28 houses.

Newcastle (Ireland). — *Road.* — The U.D.C. proposes to lay a road at the back of Valentia Place. The cost is estimated at £3,500.

Northfleet.—*Concrete Houses.*—The U.D.C. has received sanction to erect 70 concrete houses on the Newman "Monoblock" system. The cost is estimated at £29,900.

Penzance.—*Houses.*—The T.C. is considering details for a housing scheme.

Pershore St. Andrews.—*Houses.*—The R.D.C. proposes to erect 36 houses.

Porthleven. — *Houses.* — The Helston R.D.C. is negotiating for a site at Porthleven on which to erect 40 houses.

Pulborough.—A reservoir is to be constructed at Broomers Hill.

Rushden. — *Houses.* — Application has been made for permission to erect 120 houses in Irchester Road.

St. Asaph (Denbigh).—*Houses.*—The R.D.C. is considering schemes for the erection of 90 houses in the surrounding parishes.

St. Austell.—*Houses.*—The U.D.C. has decided to build 160 houses at Polkyth during the next four years.

South Shields.—*Quay.*—A quay is to be constructed at the deep water berth at the Albert Edward Dock.

Southwick (Sussex).—*Bridge.*—The Works Committee of the U.D.C. is considering a scheme for the construction of a bridge across the south channel to the beach.

Staines.—*Houses.*—The R.D.C. proposes to erect 48 houses.

Stanley (Durham).—*Houses.*—The U.D.C. has applied for permission to build 60 houses at South Stanley.

Sunderland.—*Houses.*—The T.C. proposes to erect 300 houses at Grangetown.

Tavarnypridd. — *Concrete Footbridge.* —The Builth R.D.C. proposes to build a concrete footbridge in place of the existing structure. The cost is estimated at £375.

Westward Ho !—*Sea Defence Works.*— A sum of £3,050 is to be spent on the construction of a batter wall on concrete pillars.

Willington.—*Houses.*—The U.D.C. has applied for sanction to erect 30 houses.

Winchester.—*Houses.*—The R.D.C. has applied for sanction to borrow £33,100 for housing purposes.

Tenders Accepted.

Birkenhead.—The Corporation has accepted the tender of Messrs. Guy & Hunter, at £5,199 15*s.*, for reinforced concrete work at the North End destructor.

Birmingham.—*Concrete Bridge.*—The Corporation has accepted the tender of Messrs. Muirhead, Macdonald, Wilson & Co., Ltd., for the construction of a reinforced concrete bridge over the River Cole.

Cheam, Surrey.—*Concrete Road.*—The Epsom R.D.C. has accepted the tender of Messrs. G. B. Hersey & Co., Ltd., at £1,685 19*s.* 2*d.*, for the construction of a concrete road at Cheam. Other tenders submitted were : J. Mowlem & Co., Ltd., £1,698 ; E. J. Harris & Co., Ltd., £1,725 ; P. Gallagher, £1,736 ; Crawshaw & Co., £1,763 12*s.* 8*d.* ; H. Taylor & Son, £1,765 ; H. Streeter, £1,995 ; Walker Weston Co., Ltd., £2,012 16*s.*; G. J. Falkner & Sons, £2,216 17*s.* 3*d.*; Chittenden & Simmons, Ltd., £2,493 18*s.*; Mears Bros., £2,536 16*s.* 4*d.*

DUBLIN.—The Dublin Commissioners have accepted the tender of Messrs. J. Dowling & Co., Rathmines, at £1,667, for enclosing and concreting the playground at Boyne Street, Dublin.

EDINBURGH.—*Concrete Water Tower.*—The T.C. has accepted the tender of Messrs. Stuart's Granolithic Co., Ltd., at £1,081 16*s.*, for the construction of a reinforced concrete water tower at the Portobello Baths.

EPSOM. — *Concrete Reservoir.* — The U.D.C. has accepted the tender of Messrs. Holloway Bros. (London), Ltd., at £14,733, for the construction of a reinforced concrete reservoir with a capacity of two million gallons. Other tenders submitted were: J. Garrett & Son, £15,300; Mears Bros., £15,678; G. E. Everitt & Sons, Ltd., £15,803; Sir William Prescott & Sons, Ltd., £18,537; H. Middleton, £19,901.

FALMOUTH. — *Concrete Houses.* — The T.C. has accepted the tender of Mr. J. H. Lobb, of Mevagissey, at £39,391, for the erection of 99 concrete houses.

GLASGOW.—*Concrete Wall.*—The T.C. has accepted the tender of Messrs. Hunter & Clark, at £4,867 18*s.* 8*d.*, for the erection of a reinforced concrete wall at the Dawsholm gasworks.

GREENWICH (LONDON).—*Concrete Jetty.* The B.C. has accepted the tender of the Concrete Piling Co., Ltd., at £17,899 15*s.*, for the construction of a reinforced concrete jetty at the Tunnel Avenue Depot.

PONTYPRIDD.—*Swimming Pool.*—The U.D.C. has accepted the tender of Mr. J. Sutherland, Abercynon, at £1,973 1*s.*, for reinforced concrete work in connection with the construction of an open-air swimming pool. Other tenders submitted were: Mackenna, Ltd., £3,700; W. T. Nicholls, Ltd., £3,601 3*s.* 6*d.*; Yorkshire Hennebique Contracting Co., Ltd., £3,525; D. J. Thomas, £3,482 9*s.* 5*d.*; F. J. Thomas, £3,211 16*s.* 11*d.*; T. Walker, £3,133 1*s.* 6*d.*; Durnford Construction Co., Ltd., £2,963 16*s.* 3*d.*; Vickey Bros., £2,641 18*s.* 11*d.*; Civil Engineering Construction Co., £2,345 2*s.*; John MacColville, £2,305 12*s.* 4*d.*; Ivor W. Thomas, £2,290 15*s.*; W. Rowkes, £2,200; W. Thomas & Co., £2,130 2*s.* 6*d.*

WELLS (SOM.).—*Concrete Houses.*—The T.C. has accepted the tender of Messrs. Burston & Hawkins, at £10,046 15*s.*, for the construction of 22 concrete houses.

WILDEN.—*Concrete Bridge.*—The Bedfordshire C.C. has accepted the tender of Messrs. Wycroft & Sons, St. Neots, at £365 10*s.*, for the construction of a reinforced concrete bridge at Rectory Farm.

Recent Patent Applications.

240,428.—C. W. Akers: Moulds for concrete blocks.

253,962.—H. Bloomfield: Concrete houses.

254,007.—T. H. F. Burditt: Hollow tiles.

254,008.—T. H. F. Burditt: Walls.

254,009.—T. H. F. Burditt: Moulds for casting structures of concrete.

254,012.—British Reinforced Concrete Engineering Co., Ltd., and E. B. Hall: Metal reinforcements of concrete cylinders.

254,018.—C. J. Cox: *In situ* building.

254,524.—W. Harris: Casting concrete walls *in situ*.

254,808.—W. Slade and C. Johnson: Blocks or slabs.

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OCTOBER 1926 **VOL. XXI No. 10**

TWENTY-FIRST YEAR OF PUBLICATION

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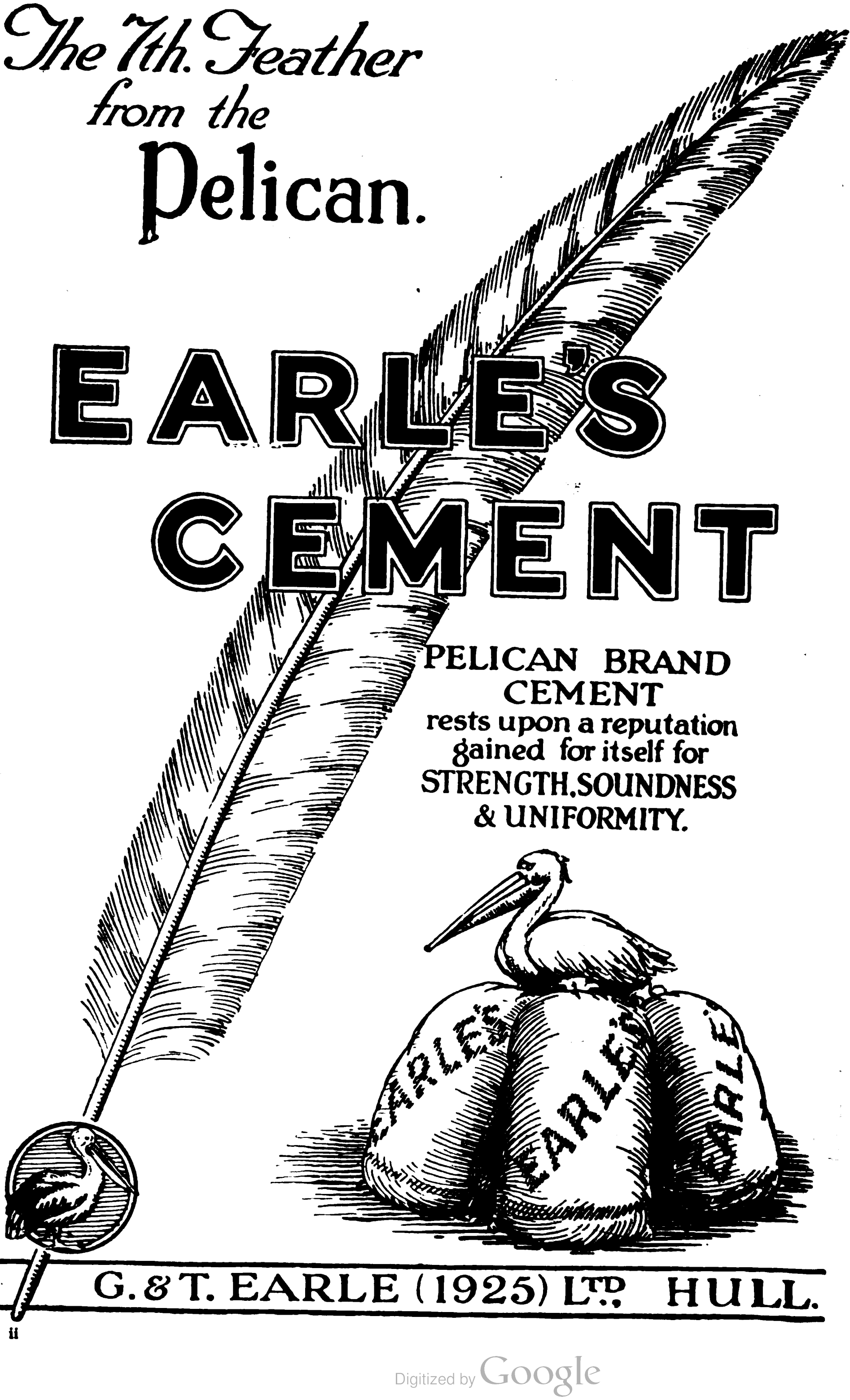

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CONCRETE
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CONSTRUCTIONAL ENGINEERING

Volume XXI. No. 10. LONDON, OCTOBER, 1926.

EDITORIAL NOTES.

Mass Concrete Construction.

ALTHOUGH a considerable amount of progress has been made in connection with the proportioning of concrete for reinforced concrete construction, comparatively little attention has been given to the important question of economy in mixtures for mass concrete. Although tremendous increase in the strength of cement has taken place during the past twenty years, comparatively little advantage has been taken of this in effecting economy in the use of cement.

At the present time under the London Steel Frame Act and Reinforced Concrete Regulations the permissible compression strength of concrete in foundations is 12 tons per square foot. In the case of the Reinforced Concrete Regulations it says that the plain concrete shall be in cement, but there is no such stipulation in the Steel Frame Act.

When we try to find out what the London County Council means by concrete, we can find no by-law later than 1891, and this by-law says that the concrete must be composed of " clean gravel, broken hard brick and properly burnt ballast or other hard material to be approved by the District Surveyor, well mixed with freshly burnt lime or cement in the proportions of 1 of lime to 6 of other materials or 1 of cement to 8 of the other material." Many engineers prefer to use a better grade of concrete for their foundations, and it is obviously absurd to allow a 1 : 2 : 4 mass concrete to be loaded only up to the same pressure as a 1 to 6 lime concrete.

In the case of mass concrete walls it is true that the Ministry of Health has to a large extent over-ridden the existing by-laws in respect of domestic houses. As the by-laws at present stand, however, there appears to have been no revision since 1891, and the concrete specified is 1 part of Portland cement, 2 parts of clean sand, and 3 parts of clean Thames or brick ballast or gravel, broken brick or stone or furnace clinkers, broken up sufficiently small to pass through a 2-inch sieve. Concrete walls made of gravel concrete to these proportions would be almost certain to give rise to condensation troubles, and, as they have to be made at least to the thicknesses of brick walls, not only will there be great waste in cement, but the walls would be much too hard for the purpose for which they were intended.

There appears to be urgent need for official recognition of various grades of mass concrete for which suitable working pressures should be specified. For plain foundation purposes where porosity has not to be considered, quite a good concrete is obtained by mixing 1 bag of cement with 1 cubic yard of clean Thames ballast, and this can be loaded up to 12 tons to the square foot with absolute safety.

Supplying Ready-Mixed Concrete.

DURING the past year or two a considerable amount of attention has been given in the United States to the supply of ready-mixed concrete from a central mixing plant. The idea of the central plant from which mixed concrete could be delivered at a distance was first put in practice on road works, where it was found more economical to have a stationary plant from which the concrete was delivered by light railway or lorry to any point within two or three hours' run than to move the mixing plant as the work proceeded. It was found, moreover, that owing to the greater care in workmanship that was possible at a stationary plant, and the opportunities for better storage of materials, a stronger concrete was obtained than when the mixer was moved with the work. Further, the supply was continuous and not subject to stoppage while the mixer was moved along.

This idea has now been further developed, and depots for the supply of mixed concrete wherever needed in the neighbourhood are frequently met with. The usual method of delivery is by motor-lorry. There are obvious limitations to this method of supply: the material must be delivered and placed before the initial set of the cement has taken place; it must be of a fairly dry consistency, or the vibration of the vehicle will cause the coarse aggregate to separate and sink to the bottom with the result that when it is tipped the water and fine materials will flow out first while the coarse material will remain in the lorry until it is dug out.

In spite of the difficulties, however, it is found that these central mixing plants are generally satisfactory, and tests on work carried out with concrete hauled for five miles showed that it was actually stronger than similar concrete on another job that had been mixed on the spot. This was probably due to the greater care and precision exercised in gauging the constituents of the concrete in the stationary plant. As a rule five miles seems the limit to which the material can be carried by road without detriment.

Strength of Roman Mortar.

ACCORDING to the *New York Herald*, some cubes of the original foundations of the Forum at Rome have been dug out and taken to the United States for test. It was found that these cubes completely crushed under a pressure of 900 lbs. per sq. in., whereas similar cubes of modern concrete were loaded to 3,000 lbs. per sq. in. before failure took place.

Reinforced Concrete Construction in Italy.

By EWART S. ANDREWS, B.Sc., A.M.Inst.C.E.

ALTHOUGH a great number of English people visit Italy every year and many of them take more than a passing interest in architecture and construction, they usually restrict their visits to mediæval and ancient buildings of which there are very many excellent examples. Attention is therefore almost solely directed to the towns of Rome, Florence, Pisa, and Venice, which depend to a large extent for their livelihood upon the visitors.

There is, however, much of interest in the way of modern construction to be found in Italy, but principally in the other towns. In Genoa—a city rather neglected by the visitors—can be seen very good examples of the mediæval palaces, and in addition a great deal of modern reinforced concrete construction. Genoa has also the advantage of being very beautifully situated on the sea with the Apennine mountains coming close up on its back, and close to it are several beautiful small seaside towns. Further, close to Genoa there are to be found two or three examples of Roman bridges in a very good state of preservation. The accompanying photograph illustrates the bridge at the small town of Nervi, about eight miles south of Genoa. A similar bridge is to be found at Rapallo, about twelve miles farther on. Both these bridges are in an excellent state of preservation, although they are not now used as wider bridges capable of taking modern road traffic have been substituted. The bridge illustrated is approximately 60 ft. in span, with an inside width between parapets of about 6 ft. It will be noted that on the day upon which the photograph was taken the bed of the river was practically dry, and is in fact being used as a drying ground for laundry. This is a very common feature in rivers which carry the mountain torrents to the sea; after heavy rain or melting of snow the torrent rushes down,

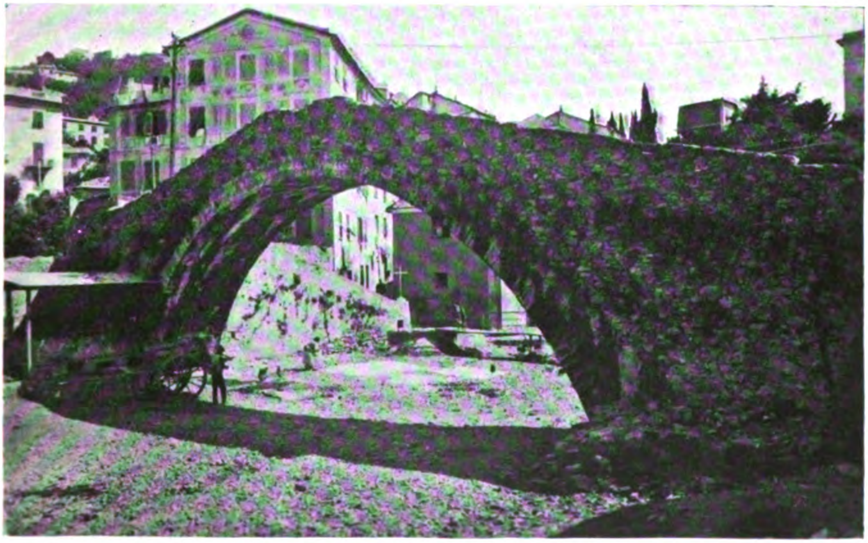


Fig. 1.—Roman Bridge at Nervi.

but in a comparatively short time it may be reduced to a mere trickle. It is of interest to note that in the case of the bridge at Rapallo the torrent has altered its course since Roman times and now does not pass under it.

In Genoa I found a veritable building boom in progress, and saw more reinforced concrete going on in one afternoon than I have ever seen in any other town. I counted more than twenty reinforced concrete buildings in course of construction in the course of a stroll of four hours. These included a very large hotel close to the main station, but most of them were large buildings about five stories in height which were to be used as flats. The Italian solves his housing problem by living in flats ; in this country we have to a large extent damned the prospect of this solution of the problem by calling them " tenements " or " model dwellings," many of which are models of what to avoid.

Although I did not make any measurements, it was clear from a glance at the frameworks of these domestic buildings that the construction was lighter than we would find necessary if designed in accordance with the regulations obtaining in this country, and as I am quite convinced that the average standard of workmanship and materials in this country is better than the average abroad, there is not the slightest doubt that reinforced concrete buildings erected in Great Britain at the present time have a tremendous reserve of strength.

I did not notice one case in which the building was a complete reinforced concrete building, that is, one in which the walls were of reinforced concrete as well as the frame. In nearly every case the floors were of a very light hollow tile construction, of which I will give some details later. The usual procedure appears to be to fill in between the columns with a kind of random stone walling on the lower stories and to use a brickwork filling—also very random—in the upper stories ; the windows are large and go practically from floor to ceiling, and in many cases open on to small verandahs. The whole buildings are plastered over,

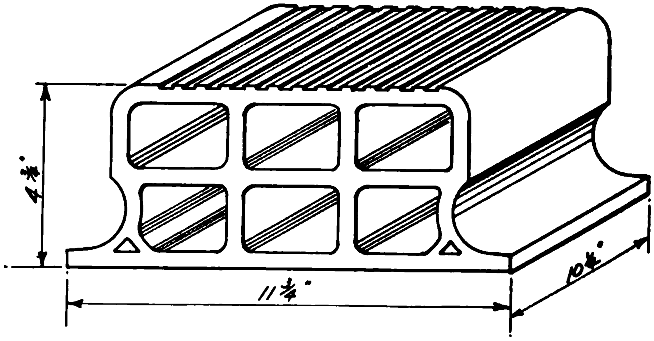


Fig. 2.

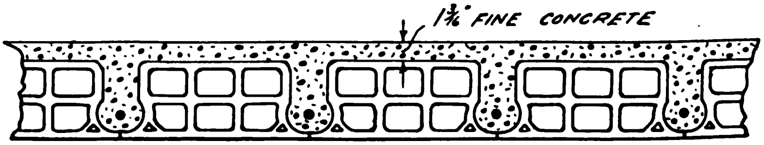


Fig. 3.

as are practically all other Genoese buildings, and when completed do not bear any obvious signs of being of reinforced concrete.

I noticed that in many cases the floor beams do not run centrally into the columns, but run so as to be flush with the edge of the column, and I wondered whether any allowance had been made for eccentricity of load ; judging by the sizes of the columns I doubt it. There was very great variation in the appearance of the centering for the reinforced concrete work ; in some cases it looked rigid and well constructed, but in many cases there were excellent examples of the Heath Robinson school of design.

Reinforced concrete is used very freely on the railways of northern Italy ; almost every station has its reinforced concrete water tank and is surrounded by reinforced concrete open-paling fencing. Nearly all the railways—including main lines—are driven by electric power, and the steel tubular standards for carrying the overhead wires are supported in pre-cast reinforced concrete sockets.

Hollow-tile Floors.

Practically all the reinforced concrete floors I noticed in buildings in the course of construction were of the hollow-tile type.

The tiles were approximately of the dimensions shown in *Fig.* 2, the webs and walls being considerably thinner than those in hollow tiles usually employed in this country, thus giving a very light form of floor with smooth soffit which possesses good fire and sound-resisting qualities.

The bottom lips are butted together and reinforcing bars are placed in the space between adjacent blocks ; the spaces between the blocks are filled with fine concrete which is also spread over the top to a thickness of about 1$\frac{3}{16}$ in. (*Fig.* 3 is a section through the resulting floor).

Floors of this kind were being erected in a seaside villa in a small town as well as in the large reinforced concrete buildings in the city ; the walls were made of the rough stone of the neighbourhood embedded in mortar, and reinforced concrete columns were employed to support a porch.

Grouted Roads in Ireland.

THE main Dublin–Belfast road, near Dundalk, is being resurfaced by the cement grout process, by direct labour under the supervision of the County Surveyor. Stone of 2 in. to 2½ in. gauge is spread to a depth of 4 in., and given a light rolling. A dry mixture of 3 parts sand to 1 part rapid hardening Portland cement is then spread evenly to a depth of ½ in. over the stone and brushed into the voids. The roller is then again passed lightly over the road. A two-to-one slurry is next applied, and sweeping and rolling continued until all voids are filled. A section of 350 yds. is considered a fair day's work, and is being carried out in half widths. No traffic is allowed on the completed surface for six days. The estimated cost of the work, inclusive of materials, preparation, and hire of roller, is 3*s*. 6*d*. per yard super.

The Fineness of Portland Cement.

A CORRESPONDENT states that he has had trouble in obtaining the necessary growth in strength between seven and twenty-eight days of a cement he believes to be thoroughly sound but which is extremely finely ground, and he asks why cements imported from England to the Tropics show smaller percentage increases between the seven and twenty-eight days' tensile tests than when tested in England.

The effect of fine grinding of cement is to hasten the development of strength, and it is therefore impossible to obtain from a finely-ground cement, giving a high strength at seven days, the same percentage growth at twenty-eight days as would be given by the same cement coarsely ground. But when cement is tested at the temperatures usually prevailing in the Tropics the growth may be still further reduced because high temperatures also accelerate the development of strength, and if test briquettes are kept at say 80° F. in a tropical climate they will show a higher strength at seven days than briquettes made in England and preserved at the specified standard temperature of 58 deg. to 64 deg. F. The effect of temperature in developing strength is usually complete in about seven days, and the twenty-eight days' tests appear to be unaffected. Hence briquettes made in the Tropics are not likely to show the same growth in strength between seven and twenty-eight days as those made in a temperate climate.

It is stated by our correspondent that with finely-ground cements the temperature rise of concrete during setting is quicker and the maximum temperature is higher than with the usual commercial cements, and the question is asked whether this is likely to be detrimental. The answer is that in the setting of cement a chemical reaction occurs which evolves heat, and in a finely-ground cement there is a large proportion of particles small enough to react with water almost immediately; therefore the rise in temperature takes place sooner, and as the evolution of heat occurs in a shorter period than with a coarse cement (which takes time for the water to penetrate the particles) the maximum temperature is higher. There is no reason why this should be detrimental, but on the contrary the higher temperature and its earlier occurrence have the effect of further accelerating the development of strength in the concrete.

It was suggested in our June, 1925, issue that the 28-days' test was no longer necessary as a test for stability, being superseded by quicker and more adequate tests, and our correspondent asks what stability test should be substituted. The Le Chatelier test is the soundness test embodied in the British Standard Specification, and this has the advantage of being more stringent and more quickly completed than the 28-day strength test.

The question is also raised as to the relations existing between setting times, hardening times, and size of particles as determined by screening for cements which comply with the British Standard Specification. A report by Professor Duff Abrams entitled "Effect of Fineness of Cement," issued by the Structural Materials Research Laboratory of Chicago, supplies the answer to this question, and the following conclusions may be quoted:

(1) The time of setting of the cement is shortened with finer grinding.

(2) In general, the strength of concrete increases with the fineness of a given cement.

(3) For residues higher than 10 per cent. the strength of concrete varies approximately inversely as the residue on the No. 200 sieve.

(4) Fine grinding of cement is more effective in increasing strength of lean mixtures than rich ones.

(5) Fine grinding of cement is more effective in increasing the strength of concrete at seven days than at ages of twenty-eight days to one year.

(6) Ordinary concrete mixtures at twenty-eight days show an increase in strength of about 2 per cent. for 1 per cent. reduction in the residue of the cement on the No. 200 sieve. At seven days, three months, and one year, the corresponding increases in strength are about 2·5, 1·7, and 1·4 per cent.

Finally, our correspondent suggests that mechanical mixing and tamping of briquettes for testing purposes might eliminate some of the human errors so frequently found in cement testing. With this we are inclined to agree if a really efficient mechanical mixer can be designed, but it would still leave unsolved the difficulty of obtaining a standard consistency of mortar for testing, and this is probably the chief cause of divergence in tests.

Reinforced Concrete in India.

REPAIRS TO AN IRRIGATION DAM.

By R. P. MEARS, M.Inst.C.E.

Fig. 1 is a view of a large earthen dam constructed for irrigation purposes in a remote part of Gwalior State in Central India. This view was taken during the dry season when there was very little water in the artificial lake. The upstream side is to the right, where the stone-pitched slope may be seen. The masonry dam, spillway, and sluice gates can be seen at the farther end.

The earthen dam is nearly a mile long, and the water it is capable of storing forms a lake of great depth and several miles in extent. With the dam in efficient working order and after a good rainy season many months' water supply would be impounded, irrigating many square miles of territory during the eight to nine months of dry weather.

As this earthen dam was found to be subject to leaks it was decided to dig a trench in front as shown in *Fig.* 2 to a depth averaging about 30 ft., and to put in a 2-ft. thick plain concrete wall of 4 : 2 : 1 mix, slightly plumed from hard rock to a few feet below the toe of the earth wall, and from this level to a level above full supply level a 9-in. thick reinforced concrete apron was placed on the pitched slopes as shown in *Fig.* 3. The amount of this 2-ft. wall carried out was approximately 120,000 square feet, and of the 9-in. reinforced apron 300,000 square feet, in which 580 tons of reinforcement were used.

As in previous monsoons there had been some discharge through the earth dam, the repair work was considered to be very urgent, and it was carried out in a single season. The contract was placed with Messrs. J. C. Gammon, Ltd., of Bombay, in mid-November, 1924, and the work was completed by mid-September, 1925.

This dam is situated about 50 miles

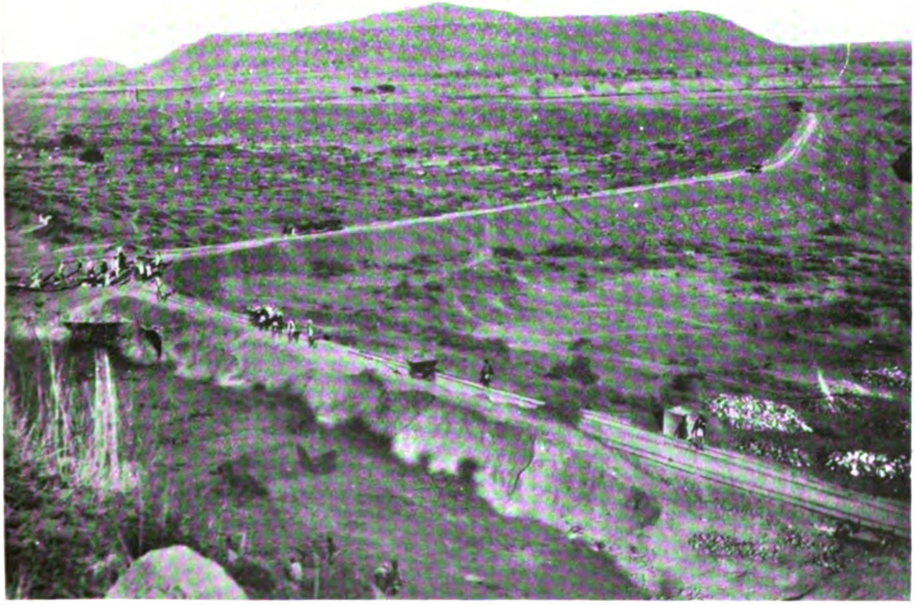


Fig. 1.

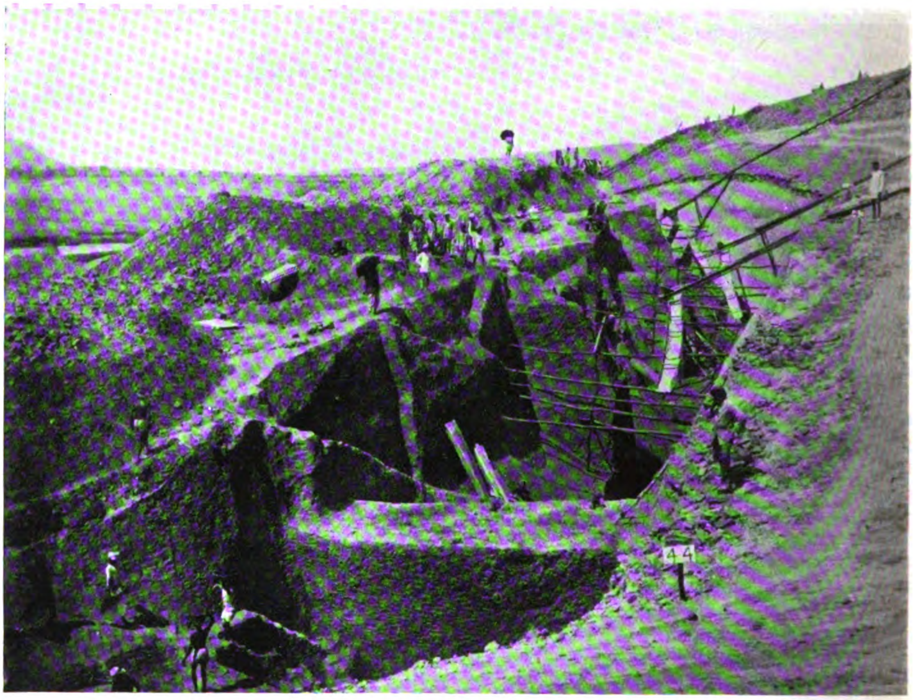


Fig. 2.

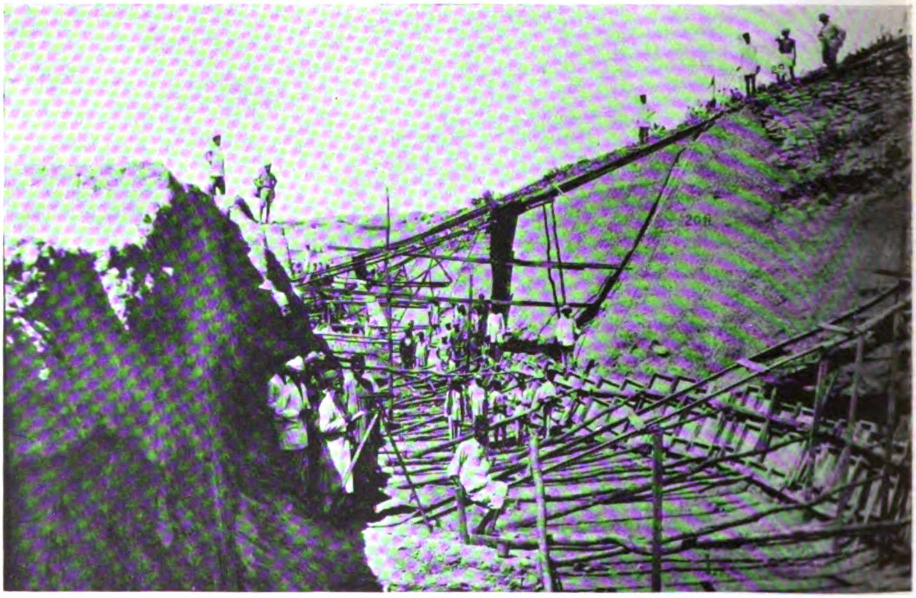


Fig. 3.

from Gwalior City, and the only means of access from the broad-gauge Great Indian Peninsula Railway main line at Gwalior is by the 2-ft. gauge Gwalior Light Railway for a distance of just over 40 miles to Jora Allapur. From Jora Allapur, there being no road, all materials had to be dragged across country for 7½ miles by either bullock carts or tractors.

The execution of this contract in the time allotted necessitated the transport of about 3,500 tons of cement, 580 tons of steel, all scaffolding and centering material, three stone crushers with engines, five concrete mixers, several pumps, miles of trolley line, tip wagons, water pipes, etc. Also cement godowns, stores, offices, engineer's bungalow, coolie lines, etc., had to be constructed in order to provide accommodation where none existed and to house cement and other perishable goods through the hot weather and rains.

Fig. 1 shows the trolley line, of which two miles were laid. Water was laid on in a 2-in. pipe with taps at frequent intervals and supplied by pumps to furnish water for concreting. Further, all these materials, machinery, and stores were carted through the open and roadless country before the rains set in and rendered cement cartage impossible and the country impassable to heavily-loaded wheeled traffic. All the plant was operated with oil fuel, coal being impracticable and timber fuel very scanty. Excavation amounted to approximately 3 million cubic feet.

Fig. 4 shows the steel sheet centering to the 2-ft. plain concrete wall, and the earth being returned to the excavated trench as this wall is brought up. The concrete chutes are also shown. The reinforced aprons, 9 in. thick, were laid on the pitching after the latter had been packed with earth and well watered. They consist of squares of 20-ft. side and are heavily reinforced top and bottom to a total of 1½ per cent. steel. The open joints were subsequently filled in with asphalt.

As more labour was required for this

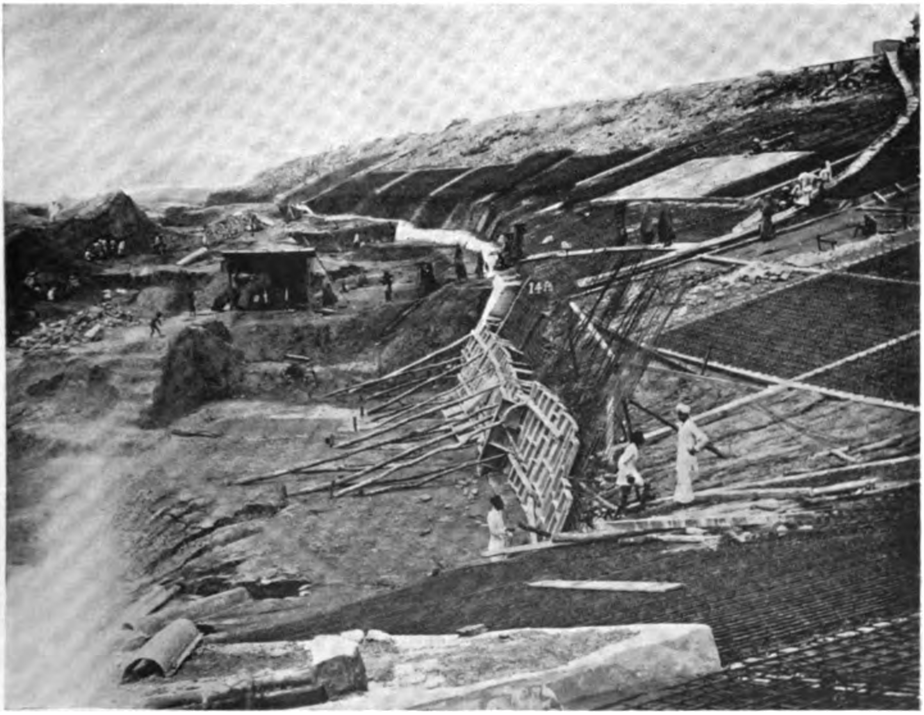


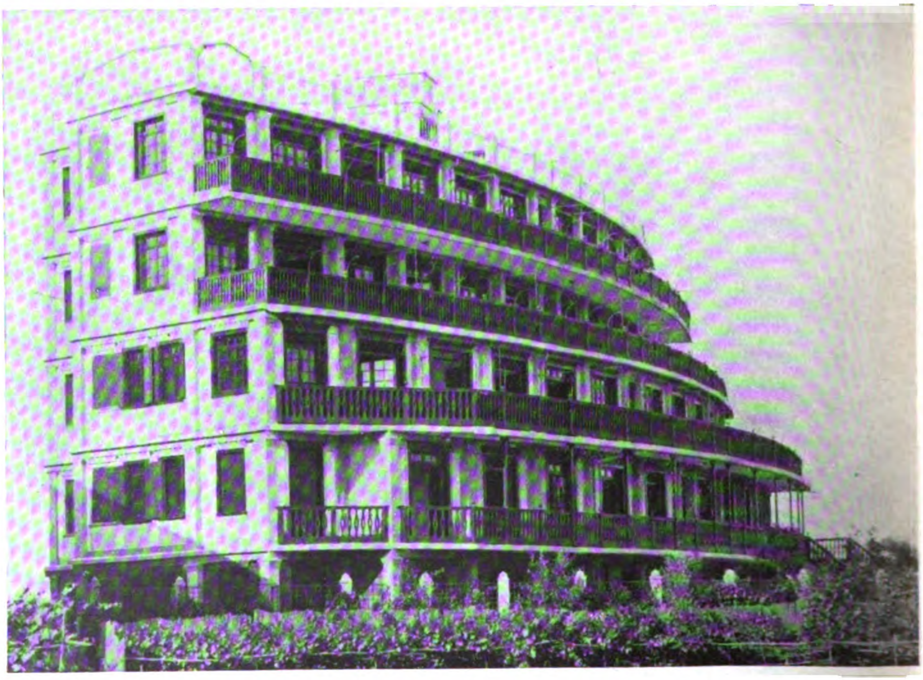
Fig. 4.

work than the locality could supply, gangs of trained concrete coolie labour were imported from Karachi, unskilled labour from Delhi, carpenters from the Punjab, supervision and superior labour from Bombay. Also scores of donkeys for transport of sand and stone were brought to the site from great distances. The housing, however primitive, of such a multitude through the hot weather and rains was a problem itself. Contract time for completion was September 30, and the last of the concreting was completed a fortnight before this; it was also necessary to have all the trench work complete before the advent of the rains late in June, which was accomplished.

The work was carried out under the general direction of Rai Bahadur S. N. Bhaduri, Irrigation Engineer to Gwalior Government. Lieut. Bhonsle, L.C.E., supervised as Resident Engineer.

A Reinforced Concrete Solarium.

THE building illustrated below has been erected on the shores of the Lido, Venice, for the accommodation of sixty-four patients undergoing sun-treatment. It is so planned that it faces the sea and is sheltered from the prevalent north-east winds. The front is curved in order that the patients, whose rooms all lead off the balconies on the front of the building, get the maximum amount of sunshine. The upper stories are stepped back so that they do not keep the sun from the lower balconies. The building is of reinforced concrete frame construction.



Reinforced Concrete Solarium on the Lido.

Restoration of Bridges at Dinan.

By **LESLIE TURNER, B.Sc., A.M.Inst.C.E.**

An interesting example of the use of reinforced concrete in the preservation and reconstruction of historic edifices is afforded by two bridges over the Rance at Dinan, Côtes-du-Nord, France. Both these old structures passed through similar vicissitudes during the war, and have recently been partially recast to suit modern requirements in such a way as to please the antiquarian eye, yet in the soundest and most economical manner, namely, with reinforced concrete.

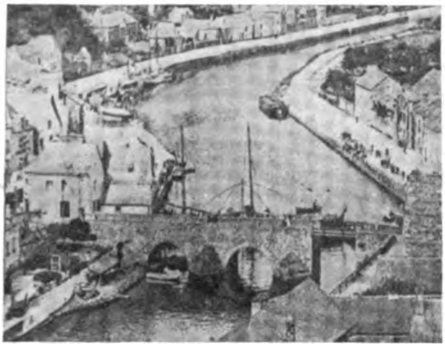


Fig. 1.

The " Vieux Pont " of Dinan, shown in *Fig.* 1, carried the original main road from Dinan to Dol before the magnificent viaduct was built, from which *Fig.* 1 was photographed. It will be noticed that the right-hand arch had then fallen. During the war, in order to allow larger barges to proceed farther up the river and by canal to Rennes, the centre arch was also demolished, and the temporary span bridging the combined gap is shown in *Fig.* 2. That casual efficiency so characteristic of the French is well exemplified by the timber under-frame strengthening the steel lattice, calling to mind a type of military trestle bridge. It will be noticed that the timbers are but roughly squared, and the raking

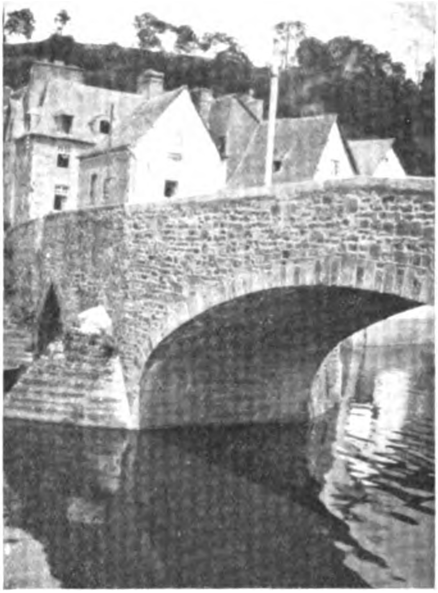


Fig. 3.

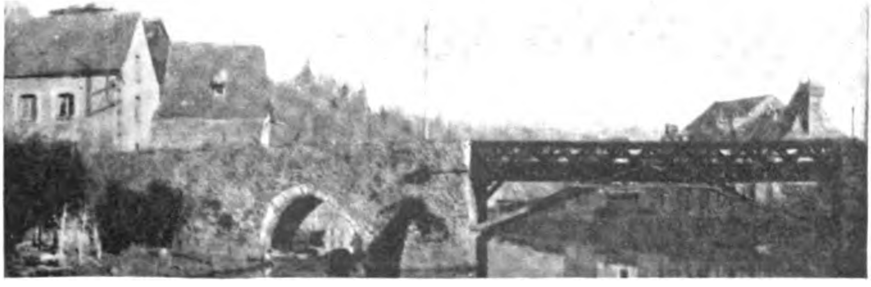


Fig. 2.

members rest in holes cut in the abutments or on corbels therefrom.

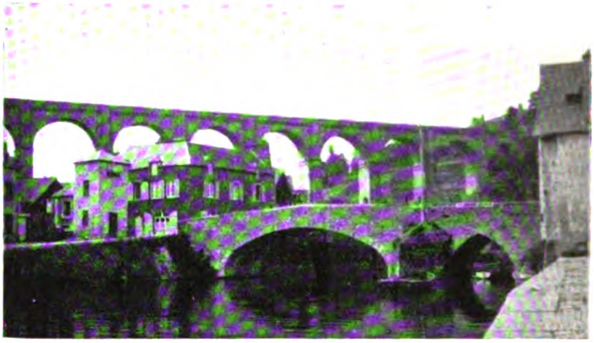


Fig. 4.

In this condition the bridge served until 1925, the smaller portion of the original bridge being preserved intact. Such historic structures, however, fall under the auspices of the French Government and it has been "registered" by the Ministère de l'Instruction Publique (Direction des Beaux Arts), as a "monument historique," forming as it does a not unimportant feature amongst other gems of building craft in a delightfully picturesque valley.

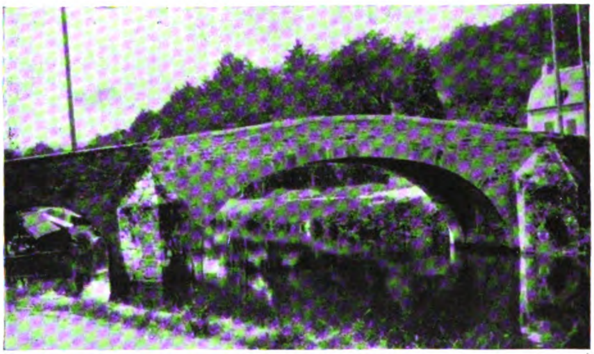


Fig. 6.

The reconstruction was carried out in the winter 1925–26, and the result is shown in *Figs.* 3 and 4. The new larger-span arch constructed on the remnants of original abutments replaces the two formerly demolished stone arches. It consists of a reinforced concrete arch slab (the board markings being plainly visible on the soffit) faced up and down stream with a granite arch ring, and with granite-faced spandrils and parapets. The whole of the new granite facing has been chosen and cut to harmonise with the old work. The photographs were taken a few months after completion and, if anything, emphasise the difference in tone between the old and

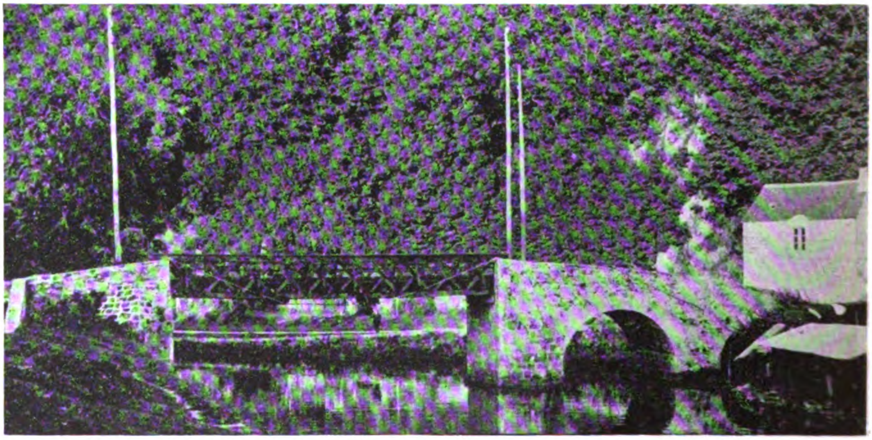


Fig. 5.

new work, although even at the present time a cursory glance at the actual bridge with its pleasant granite colouring would not reveal its novelty, while after a little weathering the difference will be hardly discernible to the passer-by.

The other bridge, at Léhon, about one mile up the river, is shown in *Figs.* 5 and 6. This originally consisted of four arches, two of which were demolished during the war and replaced by a lattice to widen the fairway. It has been similarly classed by the French Government and remodelled to tone with the old remnant and its artistic setting as well as serve the needs of the canalised river. The new portion consists of one span comprising two reinforced concrete arched ribs about 3 ft. wide supporting the intervening decking of slabs and beams, the facing, as on the Dinan bridge, being the granite of the district.

New Municipal Offices, Singapore.

THIS building, the construction of which is shortly to be commenced, is illustrated on pp. 672–3. It will have a total length of 370 ft. 6 in. by a total width of 206 ft. 6 in., and measure 63 ft. 6 in. from ground to main cornice level. The whole structure is divided into five blocks grouped around two large courtyards, and contains four floors, each approximately 5,700 yards super in extent. Provision is also to be made for an additional story on the front and rear blocks. The central block accommodates a large board room, 64 ft. by 58 ft., with galleries and domed ceiling, the roof being carried by reinforced concrete trusses. The site is an island one with frontages to form streets. The elevations at the front and sides are finished with cast stone facing and have colonnades 41 ft. high of the same material with reinforced concrete cores. The rear elevation and the elevations to the courtyards are finished in "Atlas White" cement and enriched by cast stone balustrading. A further feature is the main cornice overhanging 4 ft. 6 in. and also constructed in reinforced concrete with cast stone facing. The outer walls are in the nature of curtain walls, the whole of the loads being carried by a complete framework of reinforcedconcrete.

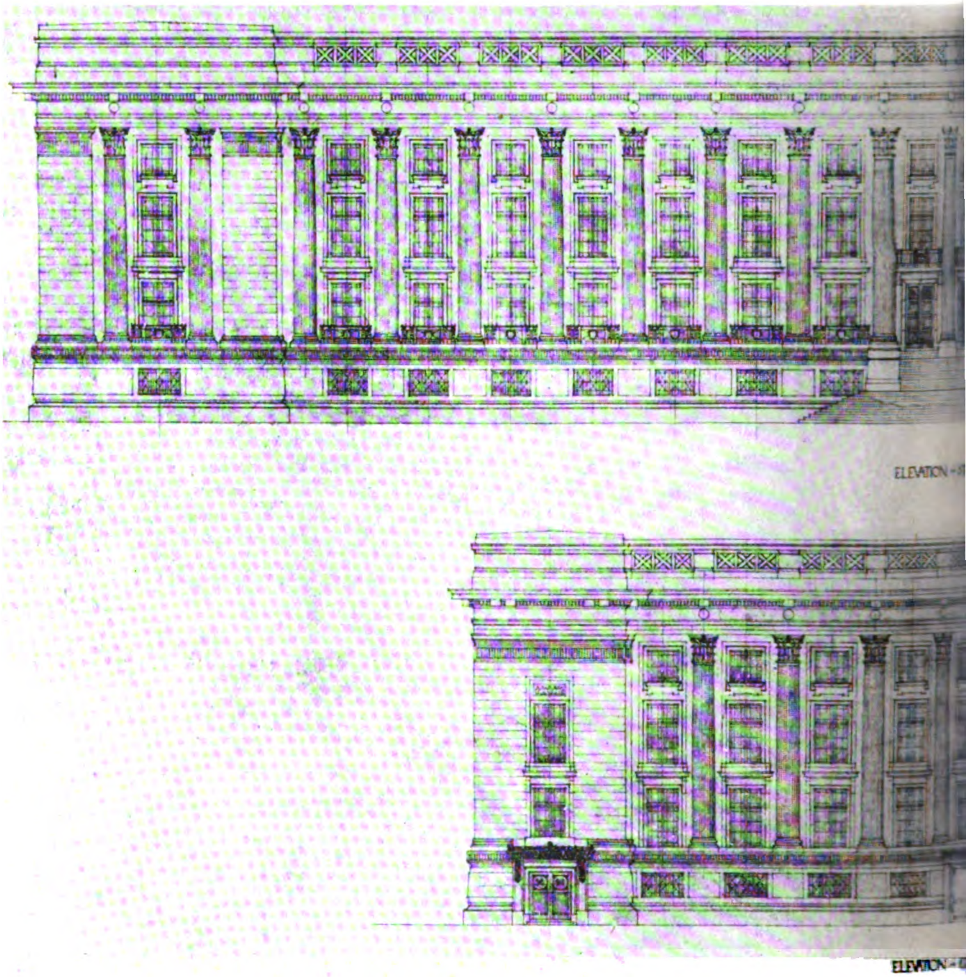
The architect is Mr. A. Gordon, A.R.I.B.A., Municipal Architect, Singapore. Messrs. Edmond Coignet, Ltd., are responsible for the design and preparation of all the necessary working drawings. The contract for the erection of the building has been secured, in open competition, by Messrs. Perry & Co. (Overseas), Ltd.

Committee for Scientific and Industrial Research.

PROFESSOR VERNON HERBERT BLACKMAN, Sc.D., F.R.S., Professor Frederick George Donnan, C.B.E., D.Sc., LL.D., F.R.S., and Professor Frederick Alexander Lindemann, Ph.D., F.R.S., have been appointed members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research, in the place of members who have retired on the completion of their terms of office.

Hospital Construction.

AN eight-page leaflet has been issued by the Voluntary Hospitals Commission (London : H.M. Stationery Office, price 2*d.*) on the construction of voluntary hospitals. Without going into details, the publication gives the general principles recommended by the Commission on such questions as the general disposition of the buildings, site, accommodation, floor space per patient, and other subjects of general application in the design of hospitals.



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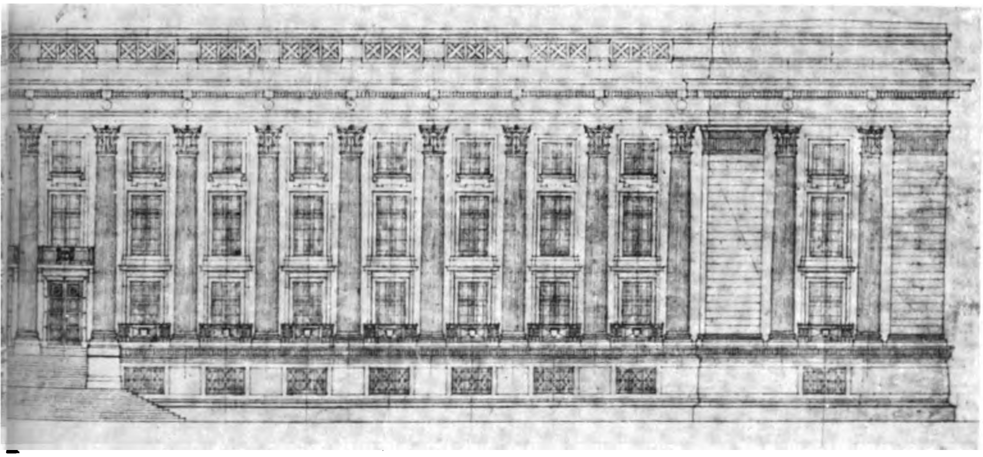

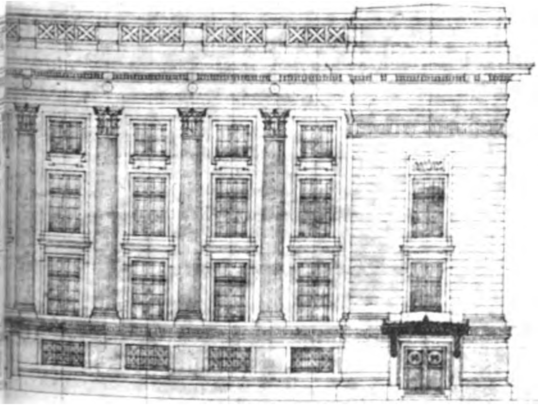

[Mr. A. Gordon, A.R.I.B.A., Architect.

ICES, SINGAPORE.

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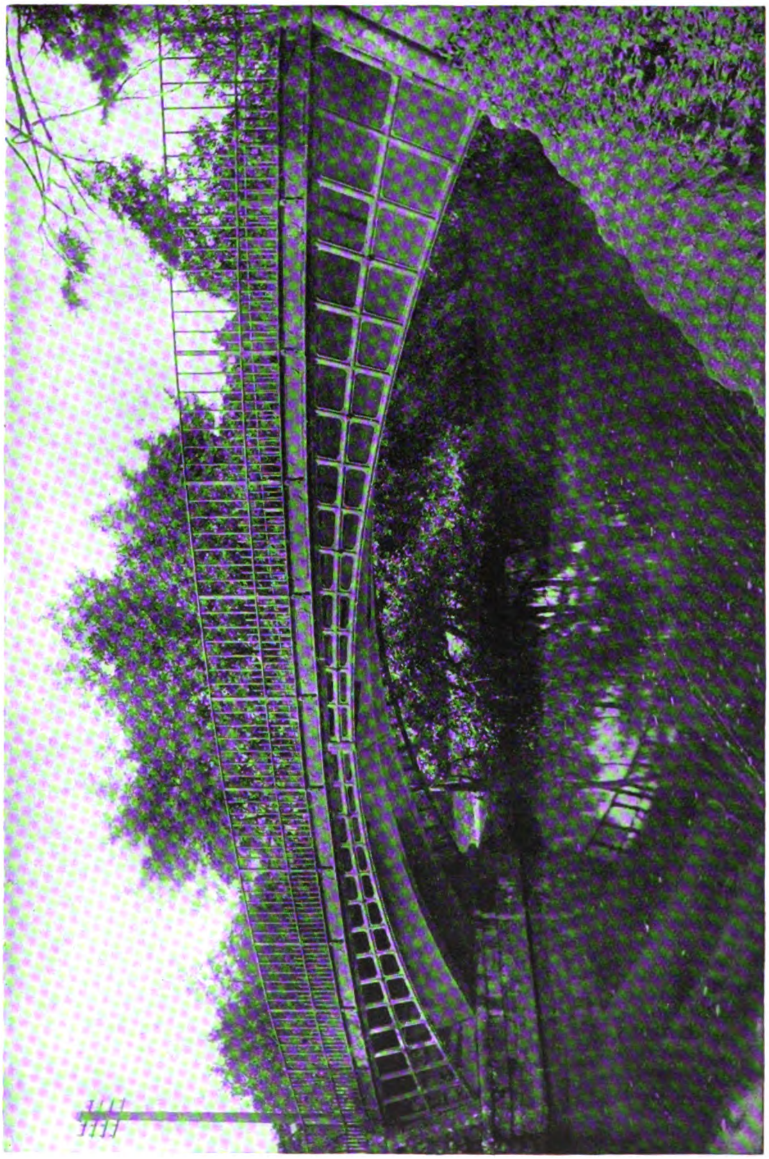


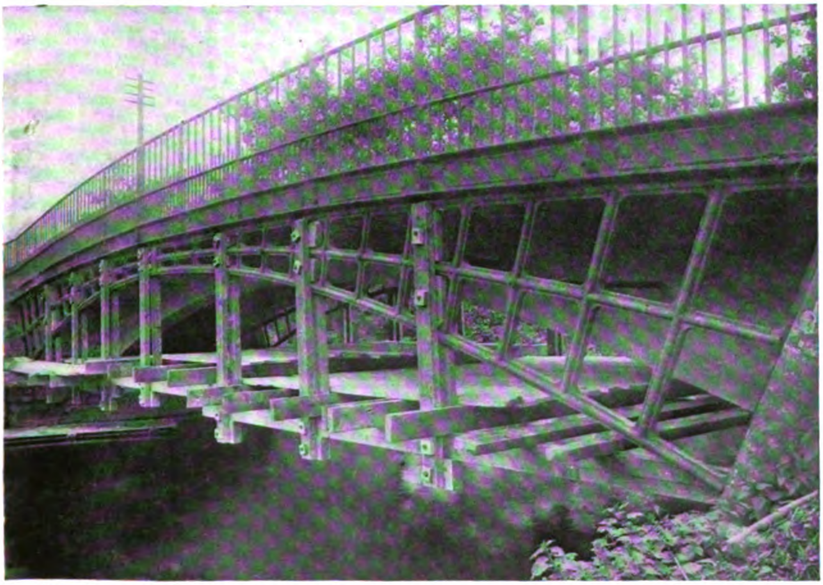
Stokesay Bridge, after strengthening.
(See p. 675.)

Strengthening Bridges with Reinforced Concrete.

At the recent congress of the Royal Sanitary Institute, held in London, Mr. T. H. Bryce, A.M.Inst.C.E., and Mr. T. J. Gueritte, M.Inst.Struct.E., read a paper entitled " Repairing and Strengthening of Metallic Bridges by means of Ferro-Concrete," in the course of which it was pointed out that many bridges built during the last century, of cast iron, wrought iron or steel, have become inadequate to carry modern traffic, mainly owing to the increase in weight and speed of moving loads and to the narrowness of the bridges themselves.

It had, said the authors, been found desirable in many cases to scrap the old bridge and erect a new one, stronger, wider and with suitable approaches. But there were many occasions when it was possible and advisable to repair, strengthen and if need be widen the old structures. First, because some had become historical, as for instance the Telford bridges, commemorating the battle of Waterloo. Second, because some were graceful and worthy examples of the engineering skill of their time. Third, because some had become, so to speak, part of the landscape. Fourth, because an important saving might be secured by judiciously chosen methods of strengthening, as well as a saving in time, and because strengthening could be carried out with less interference with traffic than would be necessitated by a reconstruction.

As far as the authors were aware the first application of ferro-concrete to such strengthening was carried out in 1900 by the Paris-Orleans Railway of France by the firm of Hennebique for a straight girder bridge at Perigueux, with a span of about 26 ft., and a width of 13 ft. The two main girders were of the lattice type; the transverse secondary beams were compound I section and supported a wooden decking. The ironwork of the bridge, which stood just outside the railway station, had been considerably eaten away by the blast of smoke and cinders from the engines. The repairs were carried out by embedding the steel work in concrete and providing extra reinforcement in the shape of round bars and stirrups. The timber decking was replaced by a ferro-concrete decking acting as top flange of the renewed beams and

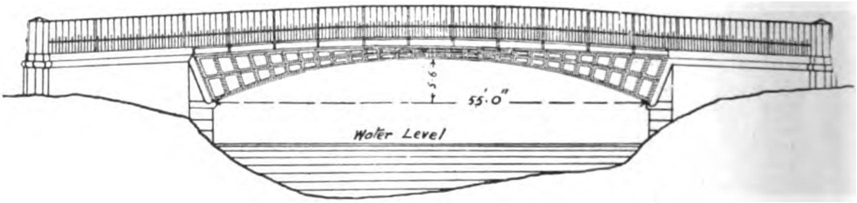


Stokesay Bridge: showing Staging for Reinforced Concrete Work.

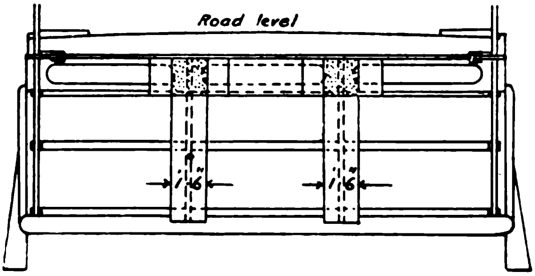
giving a monolithic character to the ensemble. The tests after strengthening were satisfactory, and Continental engineers began to utilise the method. But, generally, the old metal was merely used as a support for the shuttering of the reinforced concrete work, which was calculated to take the full stresses. Little account was taken of the old metal work in the general work of resistance. Whatever additional strength it would give to the new ferro-concrete structure was considered merely as an increase in the factor of safety. The reason for this was that the adhesion of concrete to the smooth and flat surfaces afforded by rolled steel girders, or even compound girders, was not found to be so good in practice as that obtaining between concrete and round bars of the sizes usually employed in ferro-concrete work. It was difficult, therefore, to ascertain how the old metal members would work. And, on the other hand, it was difficult to create a satisfactory connection between the old metal work and the new steel reinforcement, and to ensure that the two would work together.

Notwithstanding the good results obtained in practice on the Continent, those difficulties seem to have acted as a deterrent to British engineers, and, although the pioneers of ferro-concrete in this country submitted several schemes of strengthening to the latter, for many years after 1900 no actual application of the process was seen in this country.

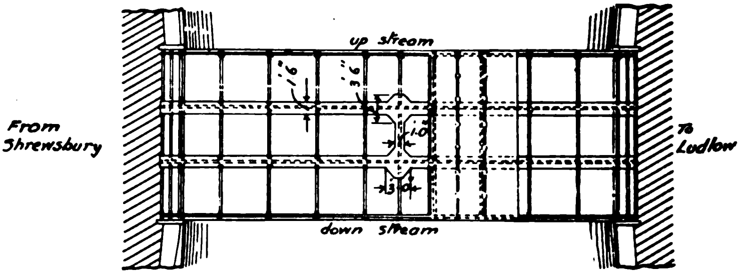
A number of bridges of the London and Brighton and South-Eastern and Chatham Railways which had suffered from corro-



Elevation of Telford's Bridge.

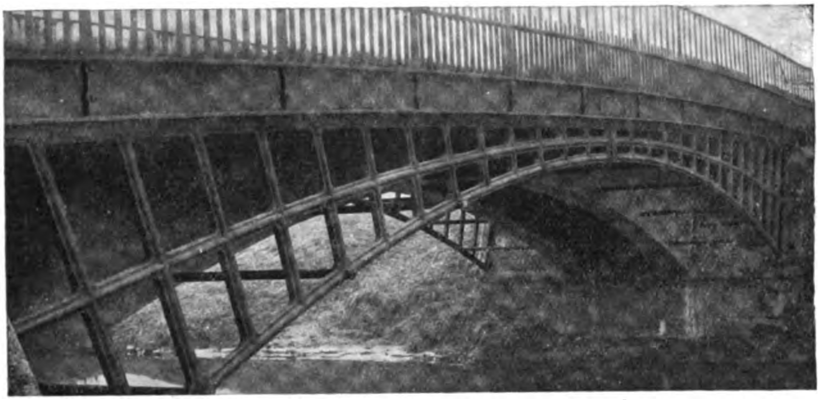


Cross-section with Ribs strengthened by Reinforced Concrete.

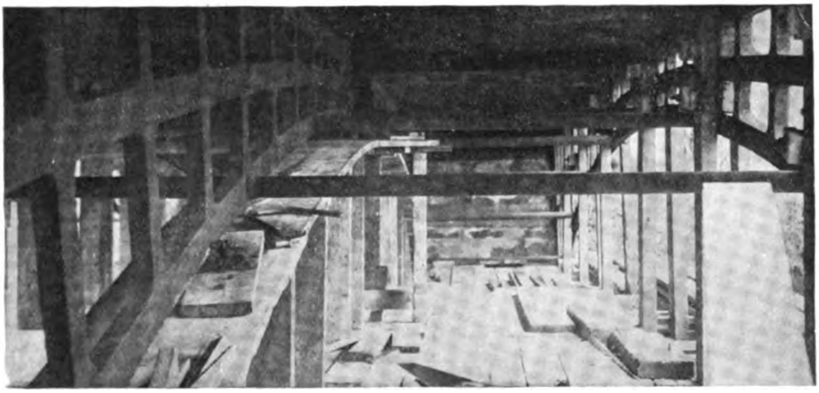


Plan showing Ribs strengthened by Reinforced Concrete.

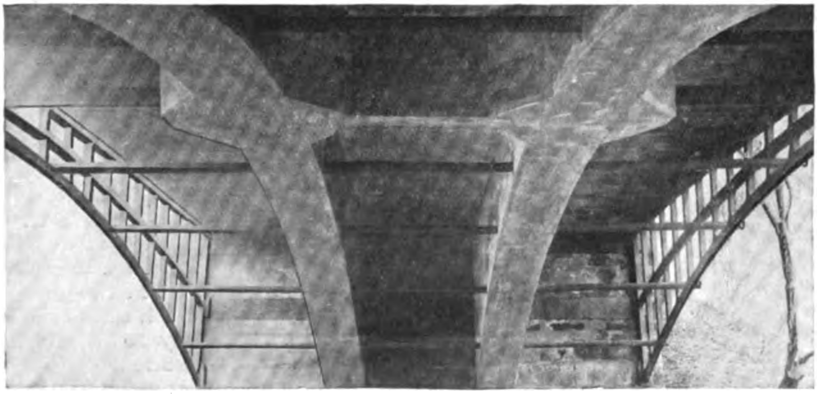
Stokesay Bridge.



Bridge as strengthened by Casing Ribs in Reinforced Concrete.



Reinforcement assembled ready for Concreting.



Reinforced Concrete Ribs as seen from below.

Cound Bridge.

sion had their metallic girders encased in concrete from the year 1908 onward, and thereby gained strength and a renewed lease of life, but no additional steel was used nor any attempt made to render them suitable for carrying greater loads.

The first real strengthening known to the authors in this country was carried out in 1917 as the result of an accident happening to a Telford bridge built at Stokesay (Shropshire) in 1822. The County Surveyor, Major A. T. Davis, M.Inst.C.E., was very desirous of retaining undisturbed, if at all possible, the external appearance of the old bridge, which had a span of 55 ft., and a width of about 21 ft. It consisted of four arched girders cast from so-called No. 2 Shropshire iron (according to Telford's specification) 1 ft. 6 in. deep at the centre and 7 ft. 6 in. at the abutments. These were all 2 in. thick cast with openings which left the upper and lower ribs and vertical bars 4 in. wide. Each girder was cast in two pieces, meeting at the centre and firmly secured together by a grated cross-piece with bolts. The foot of each girder was secured in the socket of the springing plate by wedges and iron cement. The decking consisted of $\frac{7}{8}$ in. thick cast iron covering plates.

Under the stress of modern traffic a considerable number of fractures existed in the bars (especially near the haunches) of the two internal girders. It might be said that for a distance of about 8 ft. from the springing line, the lower rib, 4 in. by 2 in. in section, was practically severed from the remainder of the structure, and the fact that the bridge stood was due to the high quality of the cast iron. The external arches exhibited no fractures, the load coming upon them being negligible.

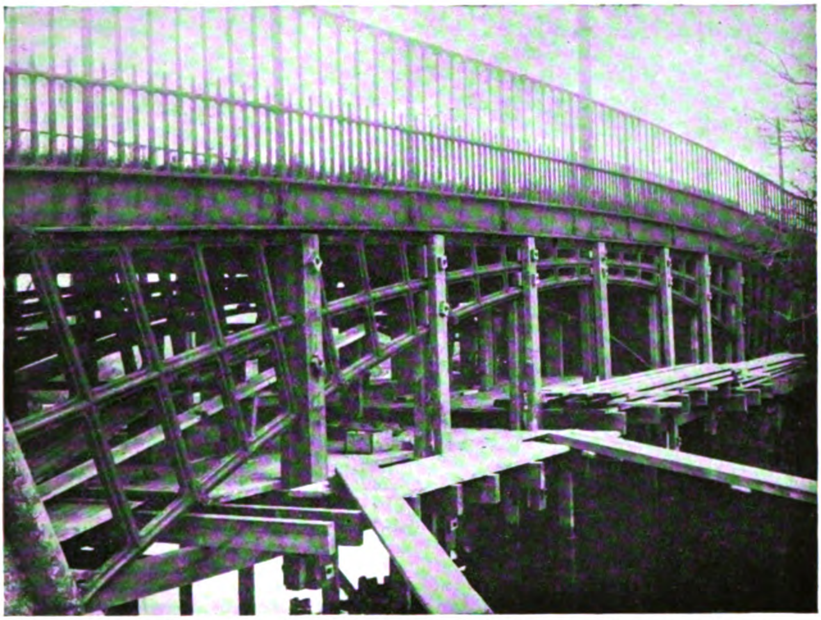
Major Davis, in collaboration with Messrs. L. G. Mouchel and Partners, strengthened the work as follows :—

To the internal ribs were added a number of round bars, some running along the full length of the intrados, others along the intrados and then rising toward the extrados in the direction of the abutments, and others running along the full length of the extrados. Vertical links of round steel connected the intrados to the extrados, and the whole of the new steel and cast iron work was ultimately encased in Portland cement concrete. The cast iron decking plates, the road surface, and the handrailings were not disturbed, as they were in good condition. The appearance of the bridge was hardly affected. The tests were carried out with a moving load of 30 tons on a 10 ft. wheel base and were very satisfactory. The cost was less than £6 per sq. yd. covered, which was considerably lower than the cost of a new bridge.

This encouraged Major Davis to proceed with the repairing and strengthening, on similar lines, of another Telford bridge constructed at Cound in the year 1818, and very similar in design, the span being identical and the width 18 ft. The cast iron, from Hazeldine's Foundry, Shrewsbury, was of excellent quality. The internal weight-carrying ribs were cracked in a precisely similar manner to those of Stokesay, but to a greater extent. Messrs. L. G. Mouchel and Partners' working details were very similar to those of Stokesay. The road surface was not interfered with and the traffic never stopped over the bridge, although the vehicular traffic, temporarily restricted to 5 tons in weight, was ordered to cross at reduced speed.

Encouraged by the good results obtained, the County Engineer for Carnarvon, Mr. D. R. Parry, carried out in 1922 a design prepared in 1910 by Messrs. Mouchel and Partners for the well-known bridge at Bettws-y-Coed, the bold letters forming part of the cast iron ribs of which declared that " This arch was constructed in the same year the Battle of Waterloo was fought." The span was 105 ft., the width 20 ft., the rise 10 ft. 6 in. The depth of the five arched girders at the crown was 3 ft. (exclusive of road material), and 13 ft. 6 in. at the haunches. The bridge was widened to 28 ft. clear, the total width of the decking being 30 ft. The provision of the two cantilevers 5 ft. wide on each side of the bridge necessitated the entire reconstruction of the decking, which was made in ferro-concrete with transverse beams 4 ft. apart, the ends of which acted in cantilever.

To keep the bridge open to traffic, the work was carried out in two operations, leaving at first one-half of the old bridge open, say a roadway 10 ft. wide. This interfered with the strengthening of the central rib, and as it was desired to keep the external ones (which had the historical lettering) absolutely untouched, the solution adopted was to strengthen consider-



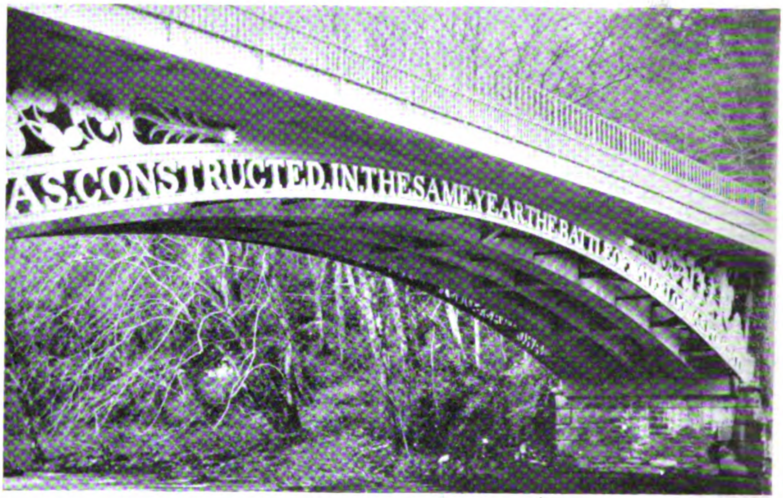
Cound Bridge, showing Staging for Reinforced Concrete Work.

ably the two intermediate ribs and to make them sufficient to carry the greater part of the load. Their scantling became 2 ft. 4 in. by 3 ft. 6 in., the spandrel walls above them being solid ferro-concrete 6 in. thick. The central rib was somewhat strengthened during the construction of the second half of the bridge. Notwithstanding the presence of the overhanging widening, the general appearance of the bridge was well preserved. The test load consisted of 40 tons on four wheels with 13 ft. from axle to axle. The cost was about £5,000, an important saving upon that of a reconstruction.

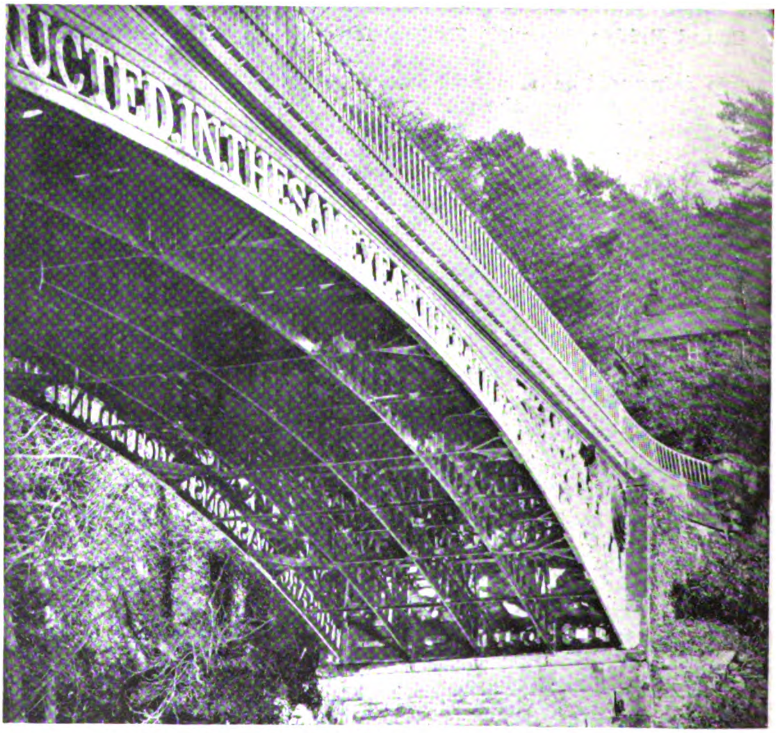
Another Telford bridge at Tewkesbury was strengthened by the help of reinforced concrete in 1923, under the direction of Mr. B. C. Hammond, A.M.Inst.C.E., County Engineer, Worcester. This bridge is an arched rib structure 164 ft. span. The cast iron plate flooring was replaced by a strong reinforced concrete floor, which distributed the loads over a greater area, and thereby secured co-operative working of the various ribs, which previously were practically independent owing to their transverse bracing being almost negligible. No attempt was made, however, to strengthen the ribs themselves and thereby allow the bridge to take full Ministry of Transport loads.

In strengthening Stokesay, Cound and Bettws-y-Coed bridges the difficulty previously mentioned was encountered. Little advantage was taken of the presence of the cast iron members in computing the strength of the repaired and strengthened work. One would not rely upon the adhesion of concrete to the smooth surface of the cast iron; means had not yet been found to repair by welding the fractures of such cast iron with any degree of security; and repairs by sleeves and bolted plates were equally out of question owing to the difficulty of drilling in such small cast iron members. The same factors militated against a proper connection being secured between the cast iron work and the additional steel reinforcement.

In a heterogeneous material like ferro-concrete the harmonious working of two materials having such a widely different modulus of elasticity as concrete and steel was rendered possible only because one knew that one might rely within known limits upon the adhesion between the two materials. If a third element were introduced, viz., cast iron, with still



After Strengthening.



Before Strengthening.

Bettws-y-Coed Bridge.

another different modulus of elasticity, and which did not adhere properly to concrete, special means must be found to force it to work concurrently with the steel. The consideration of these difficulties led M. de Boulongne of the Paris Lyons Mediterranean Railway of France to devise a new method of securing such results. The single track cast iron railway bridge at La Voulte, built in 1861, had become insufficient, if not unsafe, for modern traffic. It comprised five spans of 180 ft. each with four ribs to each span. Many members had become fractured and some of the bracings had even entirely disappeared. The cost of an entire reconstruction being prohibitive, it was desired to ascertain whether a reliable strengthening could not be secured at less cost. The Company " Soudure Autogene Francaise " being urged to improve the process of welding cast iron, succeeded in doing so, and many fractures were thus repaired during the process of strengthening. Means were adopted for thoroughly knitting together the new steelwork and the cast iron members. (Details of this work were given in "Concrete and Constructional Engineering for April," 1925.)

Encouraged by the results, the P.L.M. Railway Company had proceeded with the strengthening on similar lines of a double track bridge at Chasse, also across the River Rhone, consisting of five spans of 131 ft. each, which was in a still more defective state than the La Voulte bridge, and for which a still greater use was made of arc welding. The tests carried out a few months ago gave results strikingly similar to those of La Voulte, showing the great reliability of the process.

Another bridge of the P.L.M. Railway was at present undergoing similar treatment at Lyons. In both cases important savings were effected. Quite recently, one of the authors was commissioned to report jointly with M. de Boulongne and Mr. Hammond, County Engineer, upon the repairing and strengthening of another Telford bridge of 1820 at Holt Fleet, Worcestershire, at present in a most dangerous condition. One expected a saving of about 40 per cent. upon the cost of reconstruction. The bridge had a span of 150 ft. and a width of 20 ft., but in the process of strengthening its width would be increased to 24 ft.

An argument against the strengthening of old bridges and in favour of their replacement by new ones, was that modern traffic required wider roads, and it was considered impossible to widen old cast-iron bridges. But the examples of Holt Fleet Bridge, to be widened from 20 to 24 ft., and of Bettws-y-Coed widened from 20 to 28 ft. clear, showed that the fear was illusory.

Were it not desired to keep the external appearance undisturbed it would be possible to increase the widening further still by greater strengthening of the external ribs, and the saving on the cost of reconstruction would still remain high. The method, therefore, should receive more consideration from engineers in this country than in the past. Heed should be taken, however, of the warning uttered by M. de Boulongne: the strengthening of a metallic structure, and particularly of a cast iron one, by means of ferro-concrete required considerable experience and care, the details having to be gone into very minutely owing to the presence of the three constituting elements: cast iron, steel, and concrete. Years of experience in reinforced concrete construction, although essential, did not relieve one of the necessity of adjusting one's ideas to the new factors, and the process of adjustment could only be gradual and slow; and years of experience in the design of metallic structures went even a shorter way on the road to success for such strengthening work if it were not coupled with great skill in the handling of ferro-concrete problems. As regarded the actual carrying out of the designs, even greater care than was required for ferro-concrete work was essential, and both the contractor and his foreman should understand thoroughly the special difficulties of the work and be highly conscientious.

The Standard Consistence Formula for Cement Mortar Pastes.

By N. DAVEY, B.Sc., A.M.Inst.C.E.
(*of the Building Research Station*).

In the British Standard Specification (1925) for Portland Cement it is stated

(*a*) that in the preparation of the neat cement briquettes to be used for tensile tests, " the cement shall be mixed with such a proportion of water that the mixture shall be plastic when filled into the moulds used for forming the briquettes."

(*b*) that in the preparation of the cement and sand briquettes to be used for tensile tests, the percentage amount of water to be used shall be " determined by the following formula :—

$$\frac{1}{4} P + 2{\cdot}5$$

where P is the percentage of water required for the preparation of neat cement briquettes " as specified above.

The percentage amount of water used in the preparation both of the neat cement and of the cement-and-sand briquettes thus depends solely upon the personal opinion of the mixer ; he has to use his own judgment as to what consistence constitutes a " plastic " mixture.

It has been shown that the strength of the resulting briquettes is influenced to a considerable extent by the percentage amount of water used during mixing. This is true both for neat cement and for cement-and-sand mixtures. Further, there is one particular percentage amount of water which yields the maximum strength—provided other factors, such as the properties of the cement and sand, and the methods of mixing, curing, and testing remain unaltered. This percentage of water is that which produces a mixture of maximum density, and by making density measurements upon a number of trial mixes the required amount

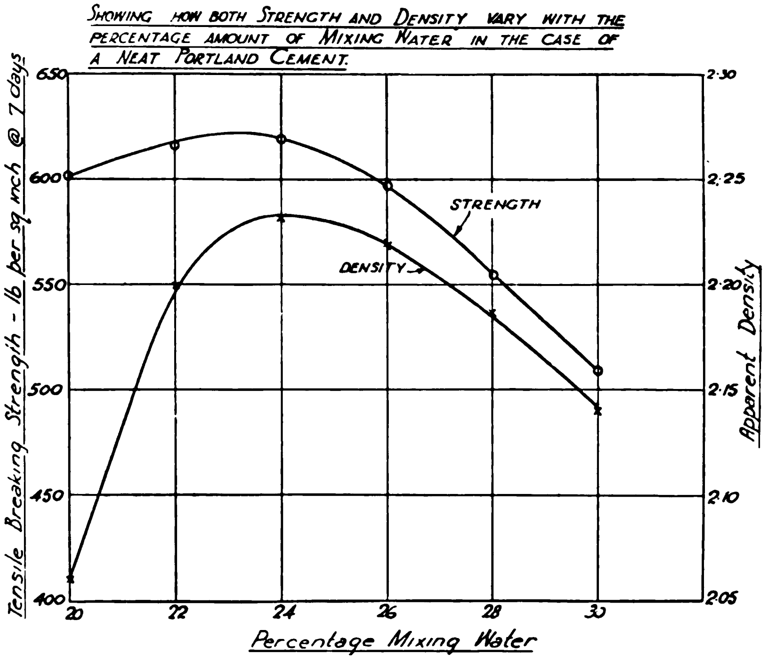

SHOWING HOW BOTH STRENGTH AND DENSITY VARY WITH THE PERCENTAGE AMOUNT OF MIXING WATER IN THE CASE OF A NEAT PORTLAND CEMENT.

Fig. 1.

of water to give maximum strength can be determined.*

It has also been shown that a paste which gives a spread on the " flow table " of 4½ inches will give the desired consistence with sufficient accuracy for practical purposes. The determination of consistence by such a method is a much more satisfactory procedure than relying so completely on the personal judgment of the test operator.

The curves in *Fig.* 1 illustrate the points mentioned above, and show how both strength and density vary with the percentage amount of water used in mixing. It will be noted that the maximum strength and density are both obtained in this case with 24 per cent. of water, and that either more or less water results in a decrease in these properties.

The main purpose of this note, however, is to show that if the percentage amount of water *P* required to give maximum strength with neat cement is determined —say by the flow table method—then the percentage amount of water to give maximum strength with any mixture of that cement and a particular variety of sand can be determined by means of a formula such as that stated in the British Standard Specification.

Two series of experiments were conducted at the Building Research Station, and in these were employed different grades of sand, viz.—

(1) Leighton Buzzard " standard " sand (i.e. sand of the white variety of the size specified in the British Standard Specification). This sand passes a sieve having 20 × 20 meshes per square inch, and is retained on a sieve having 30 × 30 meshes per square inch. The nominal diameter of the grains is between the limits of 0·0225 in. and 0·0336 in.

(2) Leighton Buzzard white sand of a finer grade than the standard sand. The nominal diameter of the grains in this case was between 0·0216 in. and 0·0233 in.

It is noteworthy that the formula deduced from the first series of experiments is exactly that quoted in the British Standard Specification for Portland Cement (1925), though the symbol *P* has a more definite value in the notation here used. The experiments thus afford an interesting experimental justification of the empirical formula employed there, and show that its form has a logical significance. In each of the series 1 and 2 the relationship between strength and percentage of water was determined for eight different mixes, and curves exactly similar to that shown by curve (*a*) in *Fig.* 1 were obtained. The mixes were as follows :—

Cement.	Sand.
1	7
1	5
1	3
1	2
1	1
2	1
4	1
neat	

The curves for the various mixes in series 1 are all plotted in *Fig.* 2. Those for series 2 are plotted in *Fig.* 3.

There are several interesting deductions to be made from these curves.

(1) For any particular mix containing a definite cement-sand ratio there is a more or less definite percentage of water which yields the maximum strength for that mix. In most cases the strength falls off rapidly from this maximum value when the percentage of water is altered, i.e. either increased or decreased.

(2) Generally the strength of the mixture is more seriously affected by a decrease in the percentage amount of water below the optimum quantity than by an increase.

(3) The briquettes made with neat cement are not as strong as those containing a limited quantity of sand. Thus in series 1 the maximum strength of the neat cement briquettes is 745 lbs. per sq. in., while that of the mixture containing 1 cement and 1 sand is 980 lbs. per sq. in. Similarly in series 2 the maximum strength of the neat cement briquettes is 775 lbs. per sq. inch while that of the mixture containing 2 cement and 1 sand is 970 lbs. per sq. inch.

(4) This may be accounted for by the fact that the initial stresses which are set up during the setting and hardening of the neat cement briquettes are very severe. These stresses are relieved to some extent when sand is present by the prevention of excessive distortion through a more equalised distribution of stress.

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* For further information and for detailed instruction for carrying out tests on consistence, reference may be made to Building Research Technical Paper No. 5 on " The Consistence of Neat Cement Pastes, Mortars and Concrete," by the author.

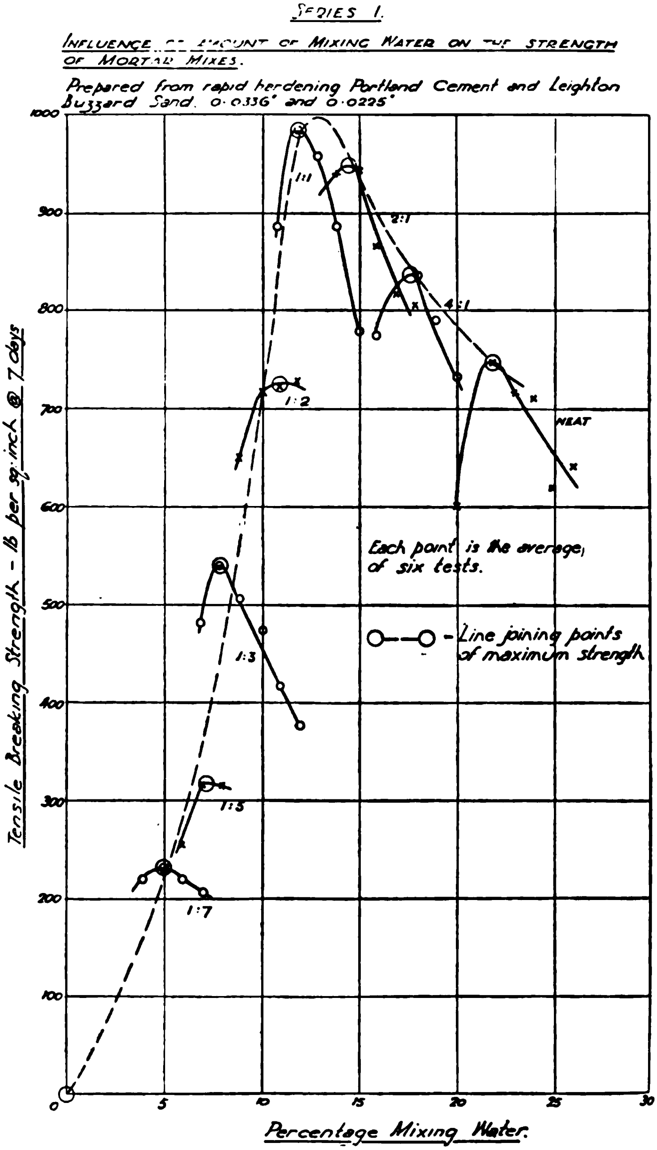
SERIES I.
INFLUENCE OF AMOUNT OF MIXING WATER ON THE STRENGTH OF MORTAR MIXES.
Prepared from rapid hardening Portland Cement and Leighton Buzzard Sand. 0·0336" and 0·0225"
Tensile Breaking Strength - lb per sq. inch @ 7 days
1000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
Percentage Mixing Water.
1:1
2:1
4:1
1:2
NEAT
1:3
1:5
1:7
Each point is the average of six tests.
○—○ - Line joining points of maximum strength

Fig. 2.

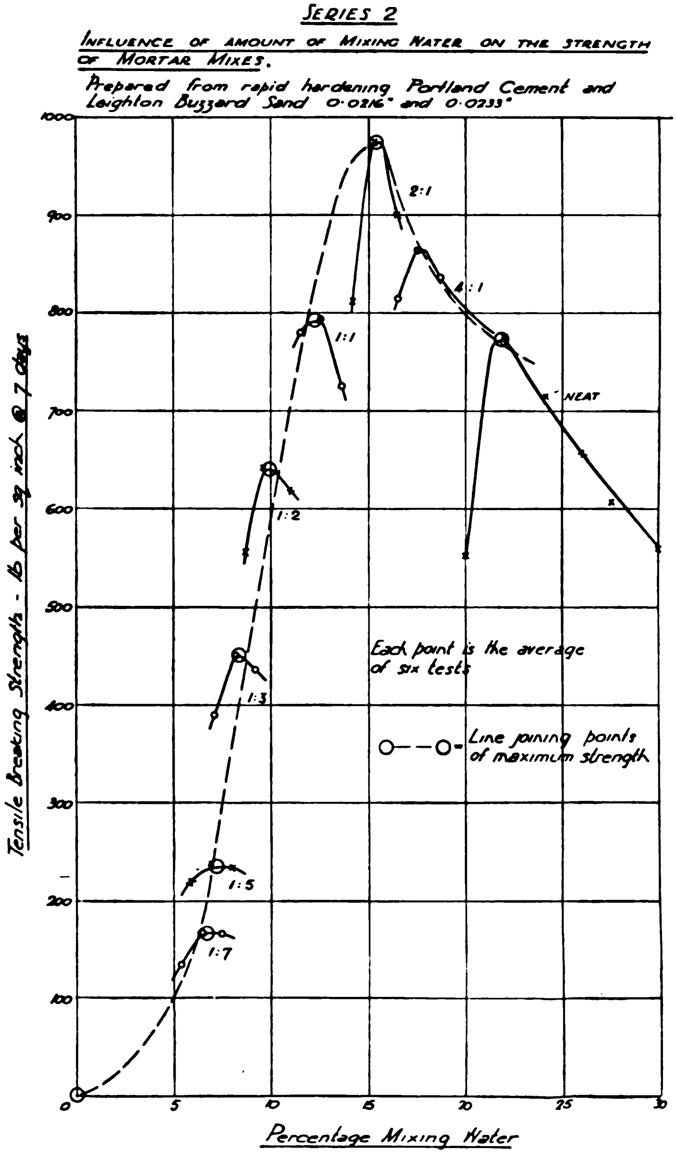
Series 2
Influence of amount of Mixing Water on the strength of Mortar Mixes.
Prepared from rapid hardening Portland Cement and Leighton Buzzard Sand 0·0216" and 0·0233"
1000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
Tensile Breaking Strength - lb per sq inch @ 7 days
Percentage Mixing Water
2:1
4:1
1:1
NEAT
1:2
1:3
1:5
1:7
Each point is the average of six tests
Line joining points of maximum strength

Fig. 3.

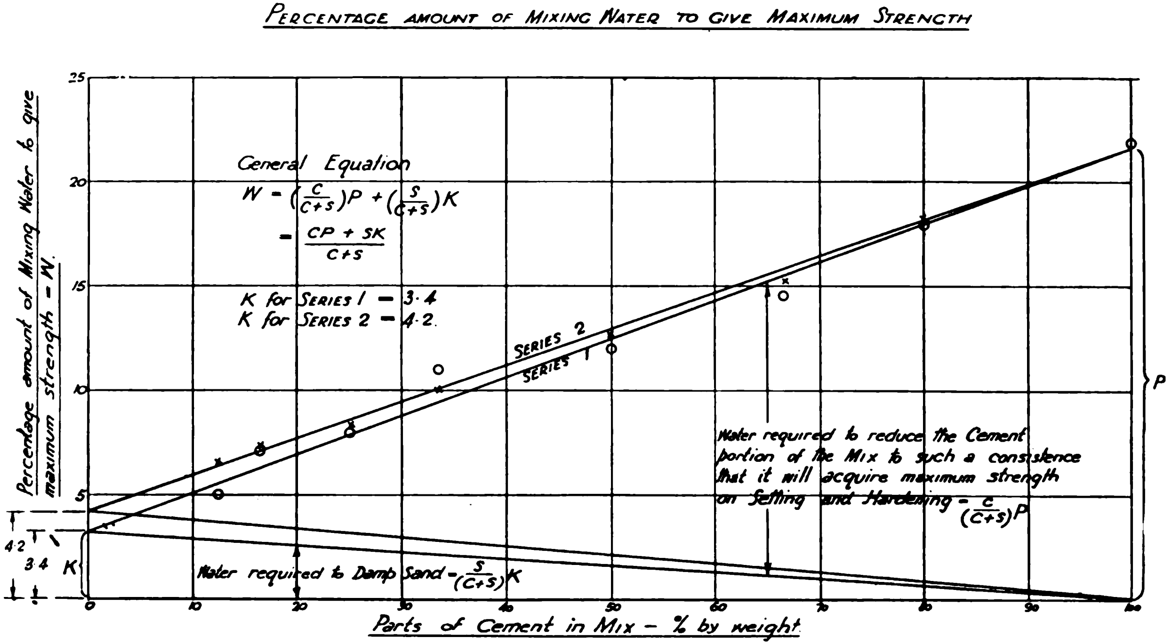
PERCENTAGE AMOUNT OF MIXING WATER TO GIVE MAXIMUM STRENGTH
Percentage amount of Mixing Water to give maximum strength = W.
25
20
15
10
5
0
10
20
30
40
50
60
70
80
90
100
Parts of Cement in Mix – % by weight
General Equation
$W = (\frac{C}{C+S})P + (\frac{S}{C+S})K$
$= \frac{CP + SK}{C+S}$
K for SERIES 1 = 3·4
K for SERIES 2 = 4·2.
SERIES 2
SERIES 1
Water required to reduce the Cement portion of the Mix to such a consistence that it will acquire maximum strength on Setting and Hardening = $\frac{C}{(C+S)}P$
Water required to Damp Sand = $\frac{S}{(C+S)}K$
P
K
4·2
3·4

Fig. 4.

Excess of sand beyond, say, 1 to 1, however, causes a rapid drop in strength, as might be expected.

On each of the separate curves in *Figs.* 2 and 3 the point of maximum strength is marked by a large circle, and it will be seen that in each figure a smooth curve can be drawn to pass very approximately through these points. For each of these points of maximum strength we have,

(1) percentage amount of water.
(2) cement/sand ratio.

Fig. 4 is therefore constructed from these data, the ordinates representing the percentage amount of water required to give maximum strength, and the abscissæ representing the cement/sand ratio, expressed as percentages.

It will be seen from the graph that the points obtained from series 1 lie approximately upon one straight line, while those from series 2 lie closely upon another straight line.

The ordinates corresponding to the mix which contains 100 per cent. cement (i.e. neat cement) is identical for the two graphs. The slopes of the two lines are, however, not identical, and if the lines are produced backwards to cut the axis through the origin (i.e. through the point which represents 100 per cent. sand and no cement) the ordinates are in this case 3·4 for series 1 and 4·2 for series 2.

To make the expressions more general we may denote the ordinate at the 100 per cent. cement point by the symbol P, and that at the 100 per cent. sand point by K. K then represents the percentage amount of water that is required to wet the sand, and it will be seen that the value of K is larger for the finer sand. K is probably largely dependent upon the surface area of the sand grains.

In this particular case, taking the average diameter of the grain in series 1 and 2 as 0·028 and 0·023 respectively, the ratio between the surface areas of equal masses of sand will be 0·82. This agrees very closely with the ratio of the two values of K, viz. $3{\cdot}4/4{\cdot}2 = 0{\cdot}81$.

From *Fig.* 4 a rational formula may be derived for the percentage of water required to give maximum strength with any particular cement sand ratio. Thus if the mixture contains C parts of cement by weight and S parts of sand, the percentage amount of sand will be $\frac{S}{C+S} \times 100$.

The percentage quantity of water required to wet this sand will be $\frac{S}{C+S} \cdot K$.

Similarly the percentage of cement will be $\frac{C}{C+S} \times 100$ and the percentage amount of water required to reduce this to the standard consistence will be $\frac{C}{C+S} \cdot P$.

The total quantity of water required for this mix is therefore

$$W = \left(\frac{C}{C+S}\right) P + \left(\frac{S}{C+S}\right) K.$$

Thus with standard sand the percentage amount of water required for 1:3 cement/sand briquettes

$$\text{is } W = \tfrac{1}{4} P + \tfrac{3}{4} \times 3{\cdot}4$$
$$= \tfrac{1}{4} P + 2{\cdot}5$$

which, as mentioned above, is the identical formula proposed in the British Standard Specification for Portland Cement.

It must be noted, however, that the value of P is obtained by the personal judgment of the operator in the latter case, while here it is suggested that it should be measured more accurately by density tests or that it should be defined for practical purposes as that percentage amount of water which will give with neat cement a spread of 4½ in. on a flow-table.

It is also apparent from the above experiments that the second factor in the formula, i.e. $\frac{S}{C+S} K$, depends upon the properties of the sand. Thus for the sand used in series 2 the formula becomes

$$W = \tfrac{1}{4} P + 3{\cdot}15.$$

The factor probably depends upon properties of the sand other than its surface area—e.g. upon its porosity.

Permeability of Concrete.

The formula for the approximate law connecting permeability and water content on p. 575 of the August number of *Concrete and Constructional Engineering* should have read $P = p\, 2{\cdot}4^{d}$, and not $P = p\, 2{\cdot}4d$.

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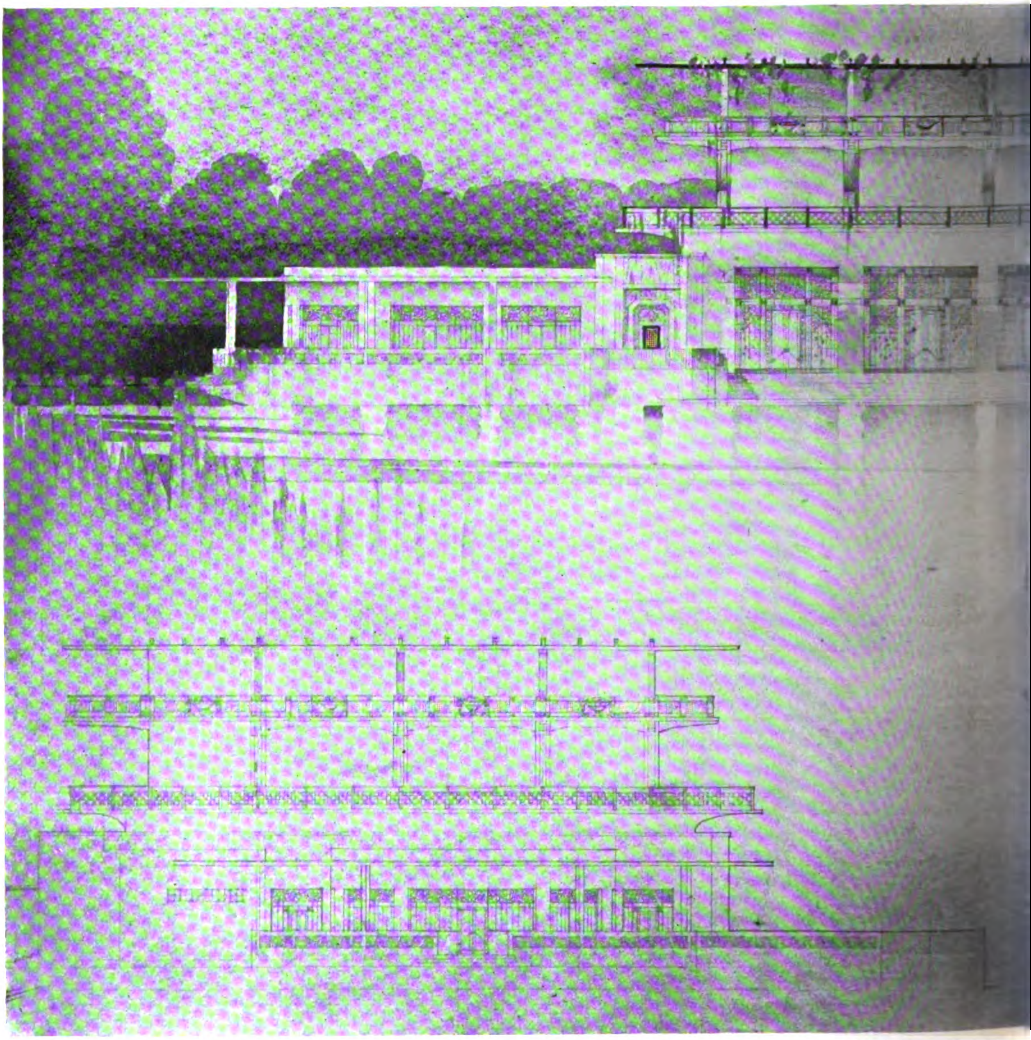
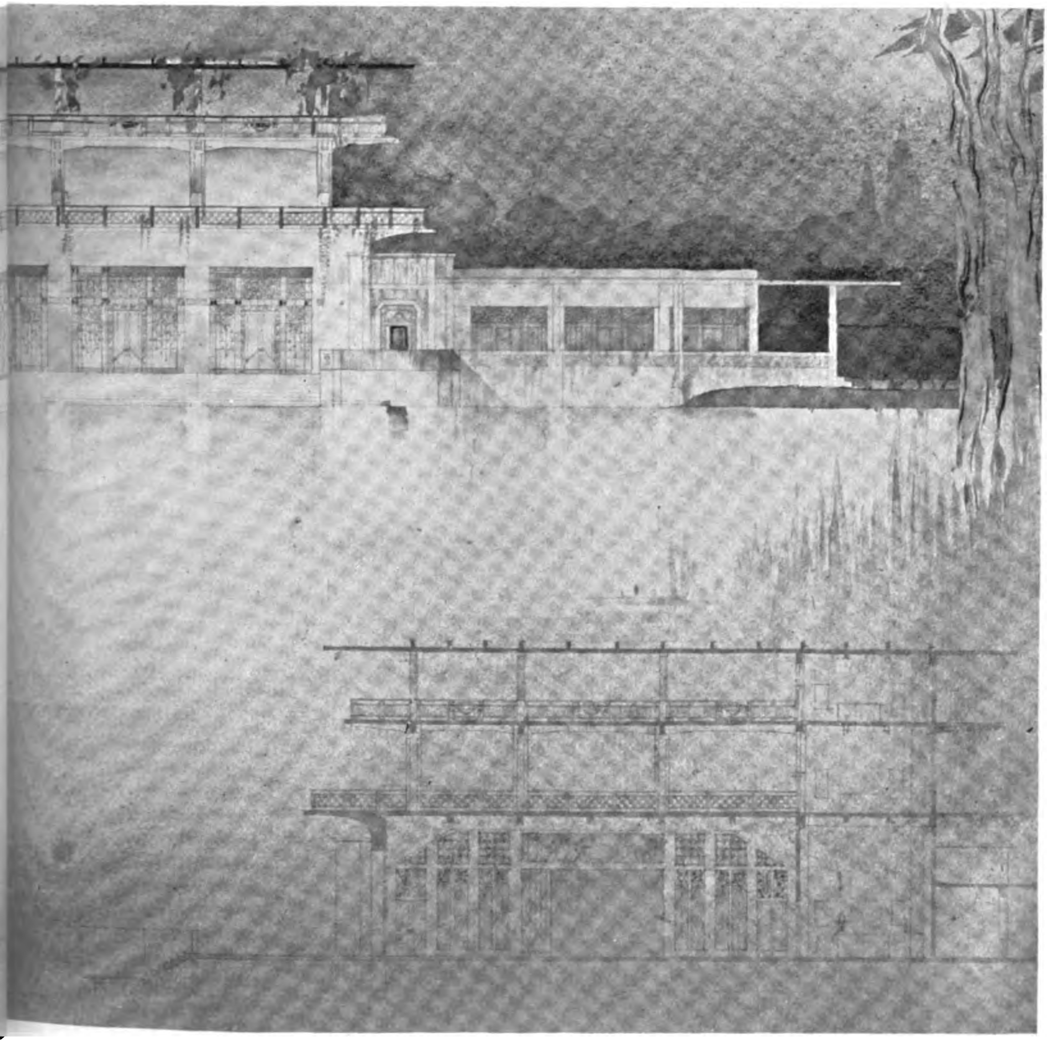


DESIGN FOR A PAVILION ON THE SERPENTINE. By Mr. S. G.

(The Winning Design and the Design awarded "F

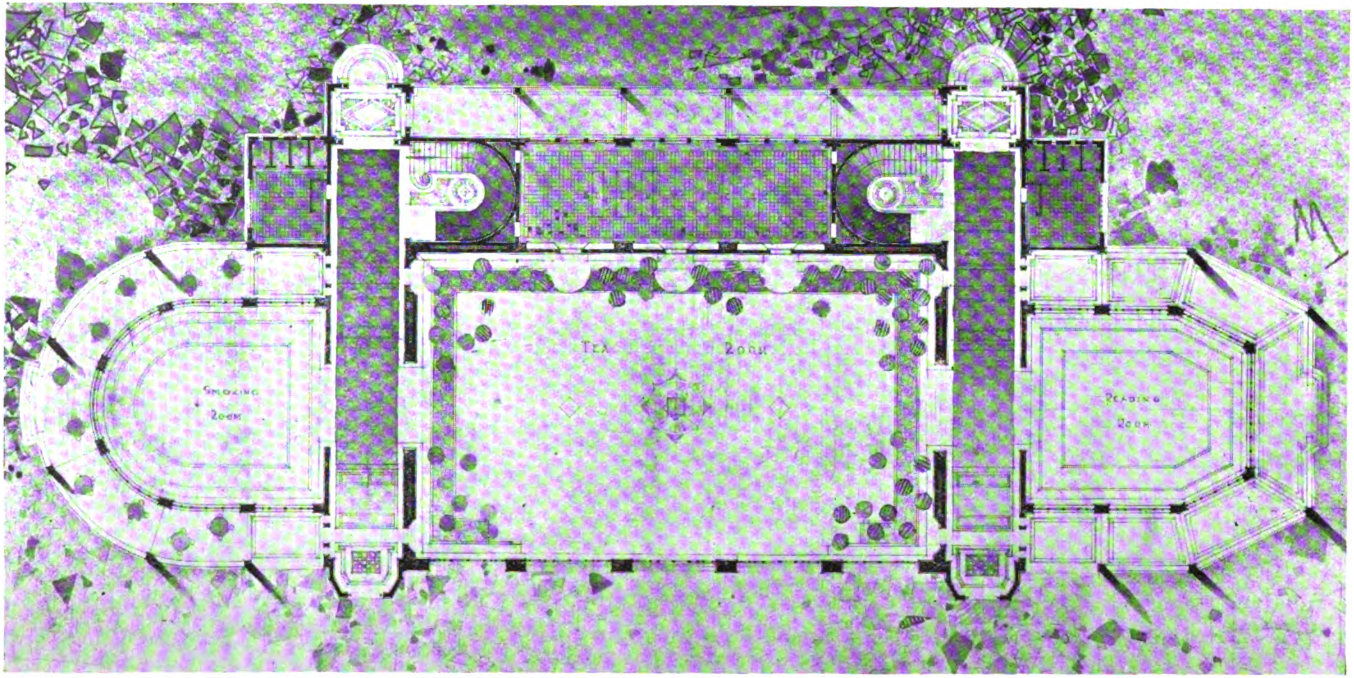
Engineering” Prize Design.



Chaplin (London University School of Architecture).—“Mentioned.”

st Mention” were given in our August number.)

"Concrete and Constructional Engineering" Prize Design.



Design for a Pavilion on the Serpentine. By Mr. S. G. Chaplin (London University School of Architecture).—"Mentioned." (*See pp.* 688–9.)

Tests on a 300 ft. Concrete Chimney.

At the 1926 Convention of the American Concrete Institute, Mr. Benjamin Wilk read a paper describing tests carried out on a 300-ft. concrete chimney at the Duluth works of the Universal Portland Cement Company during and after its erection. The tests were undertaken in conjunction with a committee of the Institute.

The chimney is 300 ft. high, 24 ft. inside diameter at the base, and 18 ft. inside diameter at the top. The thickness of wall at the base, which is also the ground line, is 36 in., tapering to 6 in. at the top. An inside concrete lining 6 in. thick starts 27 ft. above the base and extends to 145 ft. above the base. The air space between the outside wall and the lining is 6 in. The stack is supported on an octagonal base 8 ft. thick and 66 ft. in its longest dimension. The design of the stack is shown in *Fig.* 1. The chimney was designed by the engineering department of the Universal Portland Cement Co., and constructed by the Weber Chimney Co. of Chicago.

As the chimney was not under construction when the Committee had its first meeting, a good opportunity presented itself for outlining a series of tests that would be comprehensive and which would give as much information as possible on the effect not only of heat but also of wind on chimneys. The Committee outlined the tests to determine:

(1) Temperature gradient through the lining and wall of a reinforced-concrete chimney.

(2) Nature and intensity of stresses developed in concrete and steel reinforcement due to wind pressure upon the chimney and as a result of flow of heat through the wall.

(3) Wind velocity adjacent to the chimney.

(4) Distribution of the pressure on the cylindrical surface of a chimney by wind.

(5) The nature and extent of the deflection of the chimney due to wind pressure and heat.

Temperature Gradient through Chimney Wall.

In studying temperature gradient through the lining and wall of the chimney it was decided to use thermo-couples and to locate them at five heights or levels as follows:

(*a*) Just below the lower breeching.
(*b*) Just below the upper breeching.
(*c*) Just below the top of the lining.
(*d*) Just above the top of the lining.
(*e*) Near the top of the chimney.

In order to determine the variation of temperature of the temperature gradient at any particular level, it was decided to place the thermo-couples:

(*a*) In the air adjacent to the exterior surface of the wall.

(*b*) At several intervals in the chimney wall according to the thickness of the wall.

(*c*) In the air space between the wall and the lining.

(*d*) In the centre of the lining.

(*e*) In the gas stream adjacent to the interior surface of the concrete.

(*f*) In the middle of the gas stream.

A total of 30 thermo-couples have been placed in the chimney. Iron constantan thermo-couples were used. The thermo-couples in the concrete wall are of the wire type and are directly in contact with the concrete, but the thermo-couples exposed to the air and to the gas stream are of the pipe type so as not to be affected by moisture in the air or by condensation of the gases. In general the space occupied by the thermo-couple was formed by a solid steel mandrel. The mandrel carried a permanent insert consisting of a standard brass locknut, and an outside nut which clamped against the form and held the mandrel in position. The mandrel was stripped by turning the square head which projected outside the form until the mandrel was free of the locknut. *Fig.* 2 shows the design of the mandrels.

Threaded plugs were fabricated on the thermo-couple stems which screwed into permanent inserts at the face of the chimney, holding thermo-couples in a rigid position. In inserting the thermo-couples a packing of asbestos was placed around the thermo-couple wires and the concrete so as to make a watertight job. *Fig.* 3 shows the method of inserting thermo-couples; *Fig.* 3*a* is a typical section. Where the thermo-couples extend into the inner lining or far into the gas stream, a pipe sleeve was left in the

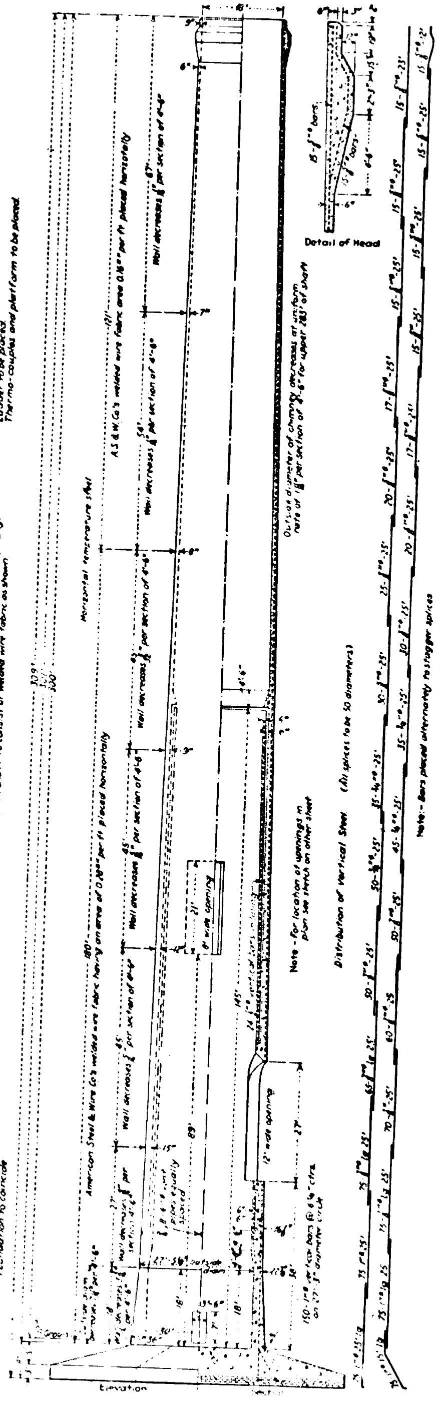

Notes - All steel kept 3" from exterior surface
Splices in steel to be 50 diameters
Concrete mix in foundation 1-2-4
Concrete mix in shaft and lining 1-2-3
Horizontal steel in lining to consist of ⅜" bars @ 14" ctrs wound spirally
Horizontal steel in shaft to consist of welded wire fabric as shown.
Lightning rod to be placed.
Ladder to be placed.
Thermo-couples and platform to be placed.
Note - Wall thickness increased 12" at bottom account steel being placed eccentric with foundation. Centers of shaft and foundation to coincide
309'
301'
300'
Horizontal temperature steel
American Steel & Wire Co's welded wire fabric having an area of 0.180" per ft placed horizontally
A.S.&W. Co's welded wire fabric area 0.180" per ft placed horizontally
Wall decreases ⅛" per section of 4'-6"
180'
121'
145'
8' wide opening
12' wide opening
27'-5¼" outside diam.
Outside diameter of chimney decreases at uniform rate of 1⅛" per section of 4'-6" for upper 183' of shaft
Note - For location of openings in plan see sketch on other sheet
Distribution of Vertical Steel (All splices to be 50 diameters)
Note - Bars placed alternately to stagger splices
Detail of Head
Elevation

Fig. 1.—Details of Test Chimney.

chimney wall to aid in removing the mandrel.

Thermo-couple readings are taken at the base of the chimney through three 10-point switches read on a Leeds & Northrup automatic cold junction compensating potentiometer with a scale reading directly from minus 50 deg. F. to plus 600 deg. F. The readings already taken show that the temperatures are quickly read directly on the dial of the potentiometer. The thermo-couples have been calibrated to ensure their accuracy.

Strain Gauge Readings.

In determining the nature and intensity of stresses developed in the concrete and reinforcing steel as a result of flow of heat through the wall, and due to wind pressures on the chimney, gauge points for Berry strain-gauge reading have been set at the eighth points around the chimney 16 ft. above the base and at three places alongside the chimney ladder at 90 ft., 135 ft., and 162 ft. above the base. Each set of gauge points consists of three points on two adjacent horizontal rods and also three points on two adjacent vertical rods. This makes it possible to get a good check on individual readings at any particular point. The length between gauge points is approximately 8 in. The Berry strain gauge can register a movement of 1/50,000 of an inch in a length of 8 in. *Fig.* 4 shows a set of strain-gauge points.

It was the idea of the Committee to take strain-gauge readings:

(*a*) Before the chimney was heated, to determine the stresses while the chimney was free from internal stresses caused by the heat.

(*b*) While the chimney was heated, to gain information on how the stresses developed as the heat rises.

(*c*) At stated intervals after a constant heat condition existed, to determine the effect of both the internal and external forces on the chimney. These measurements would also be taken during times of high wind.

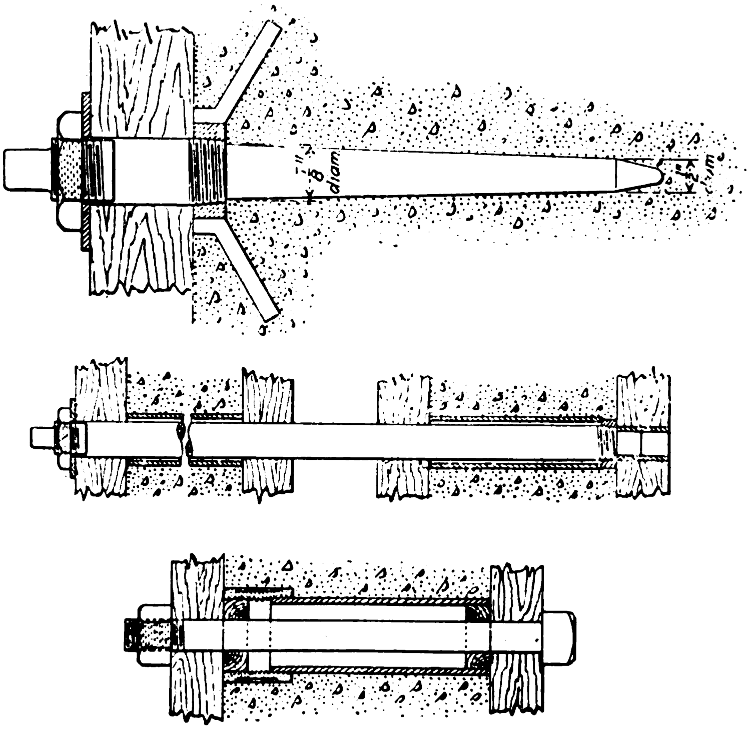
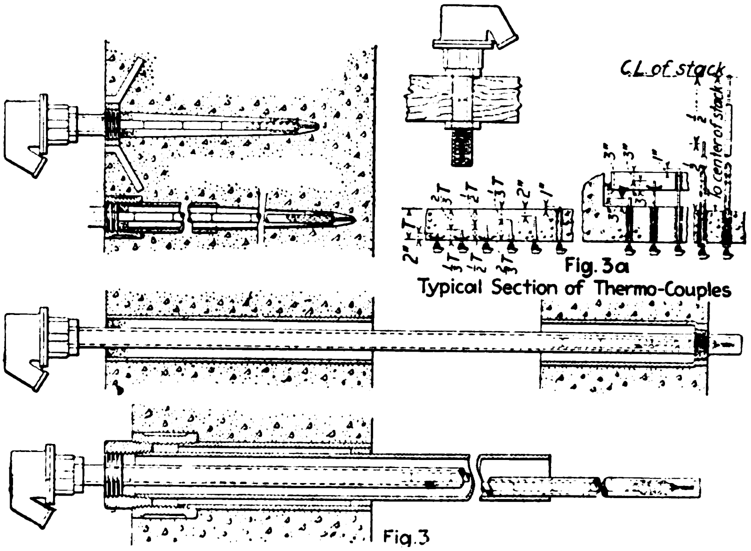


Fig. 2.—Design of Mandrels.



Figs. 3 and 3a.—Method of Inserting Thermo-Couples.

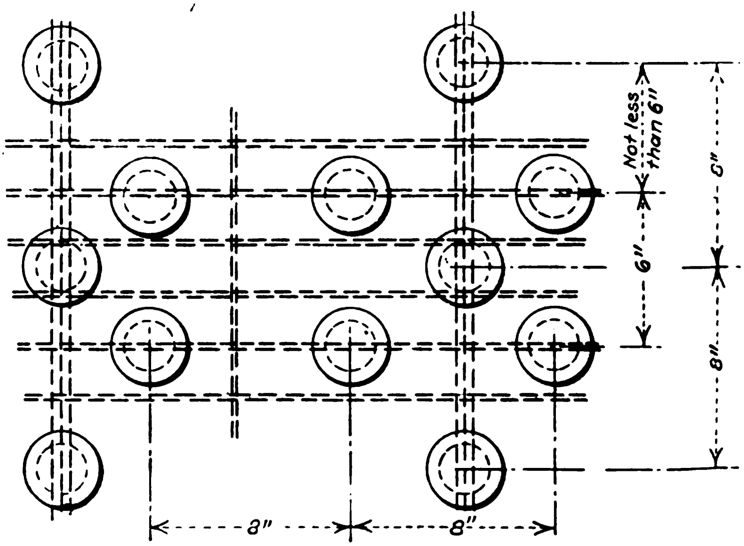


Fig. 4.—Set of Strain-Gauge Points.

Wind Velocity.

In determining wind velocity adjacent to the chimney, considerable work was done in developing a method which would be accurate. Wind velocity readings taken with U.S. Weather Bureau anemometers, which are of the revolving cup type, do not show violent gusts of wind which may last for only a few seconds. These gusts are of extreme importance and must be studied. The Burton anemometer is also of the revolving cup type but it only registers wind at a definite point. It, however, shows gusts and has registered wind velocities at Duluth as high as 130 miles per hour. It was the intention of the Committee at first to use flat plates at various points around the chimney which would register wind pressure through Pitot tubes read at the base of the chimney. The co-operation of Mr. E. N. Fales, of the U.S. Army Air Service, was obtained. He suggested the use of integrating impact pressure tubes for measuring wind velocities as well as for measuring wind pressures. This method has been used successfully in aeroplane work and has to a large extent been developed in wind tunnel tests at Dayton, Ohio. It has been found that the wind velocity and wind pressure vary considerably over a comparatively small area. For that reason small flat plates are not considered accurate. The integrating impact pressure tubes will therefore give much more accurate information as to the velocities and pressures to which the chimney is subjected than the plates originally considered.

In following Mr. Fales' suggestion, two integrating impact pressure tubes 12 ft. long at right angles to each other, forming a cross, will be set 30 ft. out from the chimney at the quarter points around the chimney. The horizontal 12-ft. integrating tube will be 234 ft. above the base of the chimney. In effect, these two 12-ft. tubes will register the average wind velocity over an area of 144 sq. ft. The tubes will be 1½ in. in diameter with holes on one side spaced 6 in. apart. As the registering of the wind pressure is effected by the curvature of the tubes, ¼-in. nipples have been inserted into the holes so that the ends of the nipples will always be at right angles to the direction of the wind. The tubes will be supported on

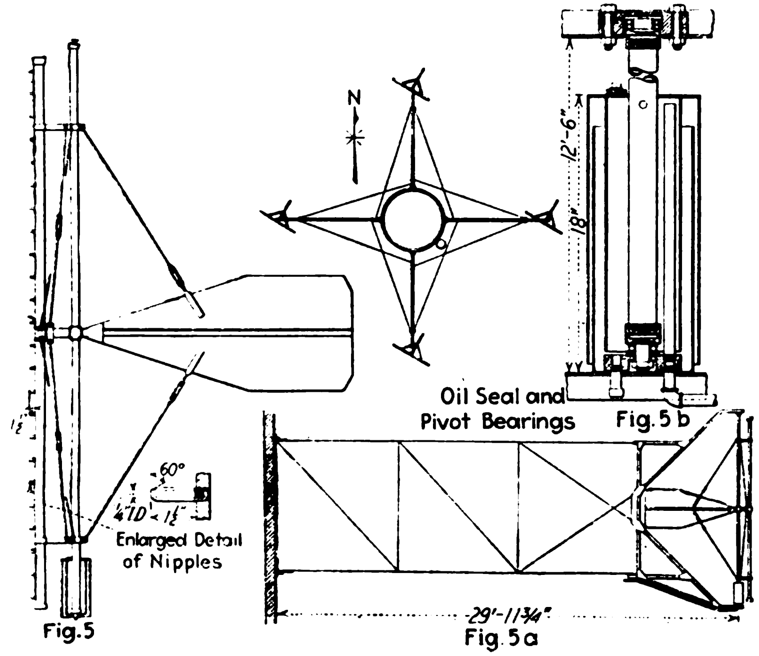


Fig.5

Fig.5a

Fig.5b

Figs. 5, 5a and 5b.—Integrating Tubes, Outrigger, and Liquid Seal.

steel outriggers and so pivoted and controlled by a weather vane that the tubes will always be in the face of the wind. *Fig.* 5 shows a detailed design of the 12-ft. integrating tubes; *Fig.* 5*a* shows the design of the supporting outriggers. The pressure exerted by the wind will be transmitted to the base of the chimney by means of a liquid seal and ⅜-in. pipe leading from the seal to the base of the chimney. *Fig.* 5*b* shows the design of the liquid seal.

Wind Pressure.

In determining the distribution of the pressure developed on the cylindrical surface of the chimney by wind forces, it was decided that pressures should be secured for two distinct reasons:

(*a*) To determine the nature of the action of wind on a cylindrical surface. Tests on small models show that a positive pressure is exerted on only a small proportion of the cylindrical surface, approximately 70 deg., while a negative pressure or partial vacuum exists on the remainder of the circumference. This theory is not as yet used in the design of towers and chimneys, but it is agreed that definite information on this subject on a chimney 300 ft. high would show the relation between coefficients as determined on a small model and on a large structure, and the data would be a distinct addition to scientific knowledge.

(*b*) Because data on wind and pressure as secured coincident to data on the stresses on concrete and steel reinforcing would effect a check on formulas for calculating these stresses.

The integrating impact-pressure tube idea as used in determining wind velocity will also be used in obtaining wind pressures on the chimney. One-inch integrating impact pressure tubes 3 ft. 2 in. long, have been placed in the face of the chimney at 18 equidistant points around the chimney. The elevation of the centre line of these tubes is 45 ft. below the elevation of the centre line of the 12-ft. wind velocity tubes, and 190 ft. above the base of the chimney. In order to register pressure accurately the tubes are attached to brass plates 4 in. wide and 3 ft. 4 in. high, the faces of which are flush with the face of the chimney. Openings in the tubes and in the brass plate are ¼ in. in diameter, spaced 4 in. on centres. The pressure in each tube is transmitted to the base of the chimney through a separate ⅜-in. pipe.

The 18 tubes were set in the chimney while it was under construction, but it is not the intention to take readings until the 12-ft. wind velocity tubes are in place. *Fig.* 6 shows the detail of the tubes in the face of the chimney, the method of attaching them to the brass plates, and the arrangement for leading the ⅜-in. pipe through the concrete to the surface of the chimney and down to the base of the stack. *Fig.* 7 shows the positions of all thermo-couples, outriggers, tubes and strain-gauge points.

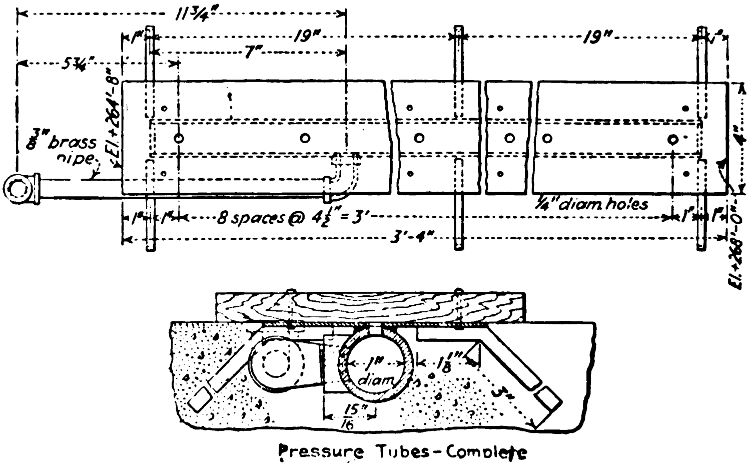


Fig. 6.—Details of Pressure Tubes.

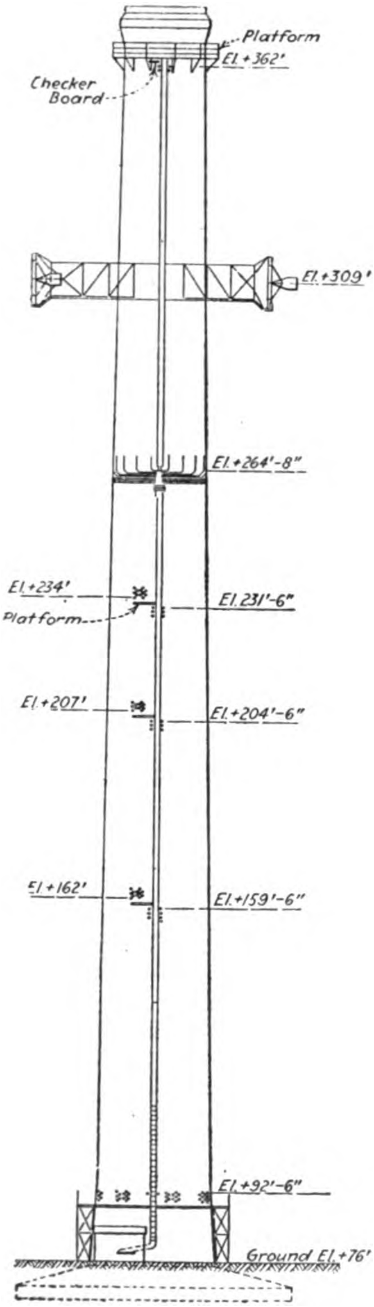


Fig. 7.—Position of Thermo-Couples, Outriggers, Tubes, and Strain-Gauge Points.

The four ⅜-in. pipes from the 12-ft. integrating impact pressure tubes registering wind velocity and the eighteen ⅜-in. pipes leading from the 3 ft. 2 in. tubes registering pressure on the chimney will be brought together alongside of each other at the base of the chimney on to a single tilting platform approximately 3 ft. wide and 4 ft. long. Glass tubes filled with coloured liquid will form the manometers to register pressure in the tubes. The record will be made photographically.

Chimney Deflection.

The nature and extent of the deflection of the chimney due to wind pressure will be determined by means of a telescope and mirror on an isolated foundation on the ground 44 ft. from the base of the chimney and a steel horizontal plate 16 in. square set firmly out from the chimney near the top of the stack. The underside of this steel plate will be painted like a chequer-board and will be illuminated so that the mirror at the ground level will reflect the chequer-board. The telescope will be rigid and any movement of the chimney and chequer-board will be read in the mirror. *Fig.* 8 shows the arrangement for reading deflections.

Work to Date.

During the construction of the chimney 6 in. by 12 in. cylinders of the concrete from each section of the chimney were made for testing. The average strength at 7 days was 1,453 lbs. per sq. in., at 28 days, 2,739 lbs., and at 3 months 4,493 lbs. The maximum and minimum variations at 7 days were approximately 33 per cent. from the average, at 28 days 33 per cent., and at 3 months 25 per cent. The specifications called for a maximum slump of not more than 4 in. After the workmen became accustomed to this requirement good results were obtained. The mix used at first was 1 : 2 : 3, but was later modified to 1 cement, 2½ sand, 2¾ trap rock graded from ¼ in. to 1½ in. The strengths of the two mixes were practically the same, but the workability of the 1 : 2½ : 2¾ mix was better than the 1 : 2 : 3 mix.

Strain-gauge readings have been taken on the concrete specimens to determine shrinkage. These strain-gauge readings show an average shrinkage so far of 0·02 per cent. Wood plugs were left in the concrete shell of the chimney as the work

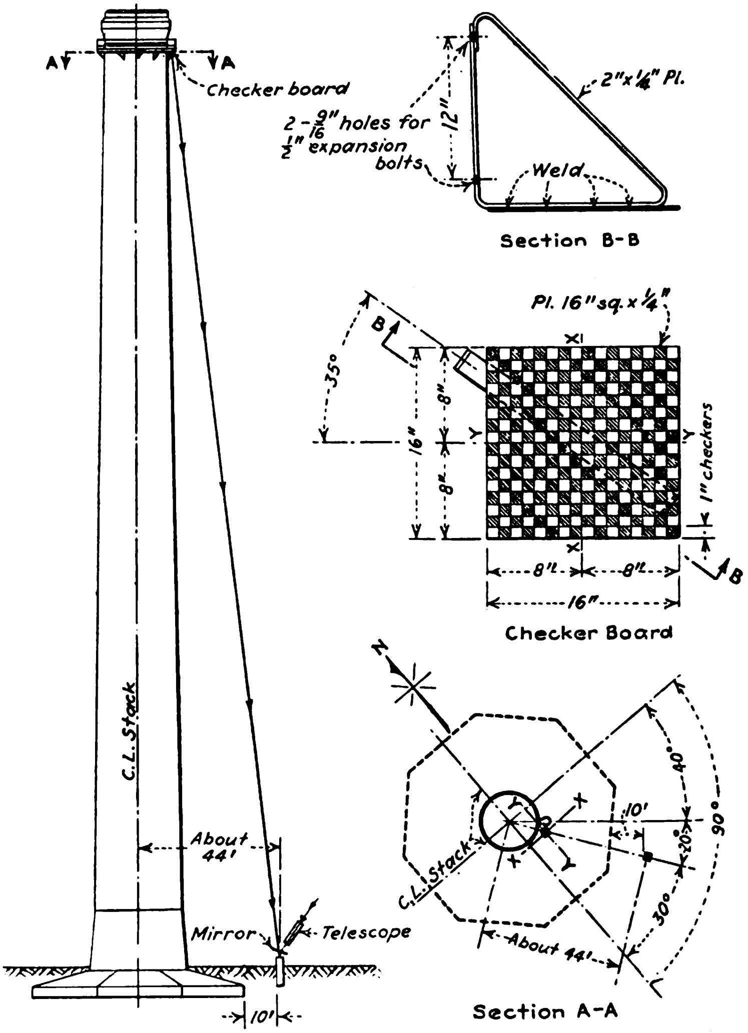


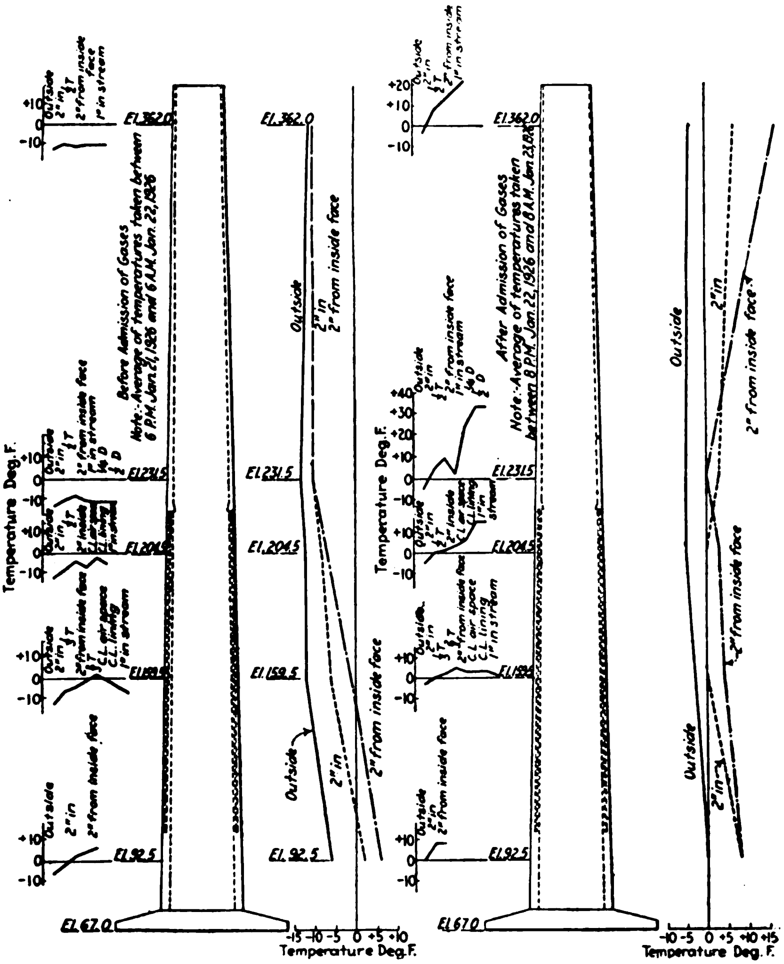
Fig. 8.—Arrangement for Reading Deflections.

progressed wherever it was necessary later to reach the reinforcement for strain-gauge points.

In order to provide for ease in obtaining strain-gauge readings, rigid platforms have been placed just below each set of strain-gauge points. The chimney ladder has also been caged for the entire height of the chimney. Close to the top a steel platform has been built all around the chimney for future experiments. It will be a simple matter to reach any point on the outside of the chimney by attaching ropes to this platform.

On January 22, 1926, gas from one of the cement plant kilns at a temperature of 240 deg., and entering at the rate of 60,000 cu. ft. per minute, was turned into the chimney, but on account of the fact that the lower breeching was still open, allowing free entrance of cold air, the temperature of the gas in the centre of the chimney was only 60 deg. F. The gas is drawn from the rotary kilns and driers, and passes through a Cottrell dust-collecting system before entering the chimney.

Temperature readings were taken every hour for 28 hours before and for 72 hours after the gas was introduced into the chimney. Outdoor temperatures during this period ranged from a minimum of



Figs. 9 and 10.

14 deg. below zero to a maximum of 22 deg. above zero. The temperature in the concrete approximated the outdoor temperature within a comparatively few hours. It was interesting to note that the effect of the heat of the sun was quickly registered by the thermo-couples. The sun's heat raised the temperature of the concrete considerably above the air temperature. The temperature of the concrete even with no heat on the inside of the chimney was higher during the middle of the day with the sun shining than the temperature of the air just adjacent to the chimney. At the Duluth chimney it will be possible to cover a wide range of temperatures because cold air can be introduced at the base of the chimney. This will be very helpful in studying temperature gradient when the gas is at different temperatures.

In view of the fact that the highest temperature of the gas on the inside of the chimney until now has not been more than 60 deg., no conclusions as to the maximum temperature gradient through the concrete shell can be given at the present time.

Readings will be taken when the breechings now open are closed and a full amount of gas is entering the chimney. At that time it is expected that the temperature of the gas on the inside of the chimney will be as high as 400 deg. Enough readings have, however, been taken to show that the temperature may vary considerably through the chimney shell. The location of the cold and warm air entrances also have considerable effect on the temperatures at a certain section. The temperature of the gas stream 1 in. from the concrete may be far below the temperature in the middle of the gas stream. *Fig.* 9 shows the average temperature at various elevations as recorded by the thermo-couples for a 12-hour period before the gas was introduced into the chimney. *Fig.* 10 shows the average temperatures for a 12-hour period after the gas was introduced.

The tests on this chimney are already attracting considerable attention because of their comprehensiveness and the unusual method of determining wind velocities and wind pressures. Readings will be taken during the next twelve months and it is expected that the report to be presented at the 1927 convention of the Institute will give conclusions as to the temperature gradient through the chimney wall, as well as data on wind pressures that will be fundamental in the design of chimneys.

Trade Notice.

New Type of Reinforcement.—A new type of mesh reinforcement for floors and roads known as "Matobar" has been designed and put on the market by Messrs. McCall & Co. (Sheffield), Ltd., of Mazda Buildings, Sheffield. There are two distinctive features in this reinforcement (which is patented); it is supplied in flat sheets, and the bars are held in position, without welding, by spacing rods which do not form part of the reinforcement. The spacing bars contain loops, which may be at any desired intervals according to the spacing of the reinforcing rods, and into these loops the rods are forced by a special tool which securely holds them in position without welding or the use of wire. The reinforcement is supplied in mats already assembled by the makers or in separate rods to be assembled on the site. In the latter case, this system avoids any possibility of the rods being placed at wrong centres as may easily happen when plain rods are wired at the crossings. The spacing bars ensure perfect alignment and rigidity, and reduce the amount of supervision necessary. A further point is that all mill-scale is removed from the rods in the process of manufacture. Messrs. McCall have issued a booklet describing this reinforcement and its application, copies of which will be sent to readers of this journal.

Book Reviews.

"Concrete Plain and Reinforced." Vol. I. Theory and Design of Concrete and Reinforced Concrete Structures. By the late F. W. Taylor, Sanford E. Thompson and Edward Smulski. Fourth Edition.

(London: Chapman & Hall, Ltd. Price 40s.)

THIS well-known work is now being republished in three volumes, the first of which is now ready and the remainder of which will follow later; vol. II will cover concrete materials and construction, and vol. III will deal with special structures in reinforced concrete.

The work is more than a text-book; it is a compendium of information, brought thoroughly up to date, dealing exhaustively with every conceivable aspect of concrete and reinforced concrete theory, design, and construction, which will leave nothing to be said on the subject if vols. II and III are as comprehensive as the first.

Such a well-known work as this does not call for a detailed review. Its comprehensiveness is obvious when it is stated that this first volume contains nearly 1,000 pages, although conciseness is one of the accomplishments of the authors. Its popularity is evident from the fact that with the present edition the work reaches its 28th thousand. Illustrations are generously used wherever necessary to explain the text, and many design tables are included.

"Cottages: Their Planning, Design and Materials." By Sir Lawrence Weaver, K.B.E., F.S.A.

(London: Country Life, Ltd. Price 15s. net.)

THIS volume of nearly 400 pages is a complete book of reference to post-war housing in Great Britain. How good is the architecture of most of the small houses built during the past few years may readily be seen from a tour of the countryside, for they are to be seen at practically every turn. From such a plethora of material—somewhere about half a million houses—the author has selected the best, and these are illustrated and briefly described. There are no fewer than 483 illustrations, the majority of them being photographic reproductions and clearly-drawn plans of small houses. To architects and others responsible for the erection of small houses the book is of great value, containing as it does such a large number of designs and plans showing what can be done in this direction. The illustrations are each accompanied by a few words of helpful criticism and suggestion by the author, and in many cases the cubic contents and cost are mentioned.

Most of the houses illustrated are of brick, but other materials are dealt with. "Concrete," says the author, "is a reasonable and proper material [for cottage building], which does not need to masquerade as natural stone," but in spite of his appreciation of the value of the material, the author apparently has a great deal of misconception as to its use. We are told, for instance, that "concrete is a very porous material and tends to let the rain through readily," and later, "There is a possibility, however, that with quite perfect aggregate, a solid concrete wall may be made impervious." One would imagine that the author has had little practical experience of the material, or has been unfortunate enough only to see the most "jerry" built concrete house in existence. We could show him many thousands of concrete houses which show no sign whatever of dampness; indeed, the problem, as the author himself points out later, is to devise methods of preventing condensation on the inner faces of the walls due to their impermeability if a gravel concrete is used throughout.

The book also states: "The building of a concrete cottage with ordinary timber shuttering means the erection of a hollow wooden skeleton. The filling of the skeleton with concrete almost constitutes the building of a second house . . . and explains why concrete cottages built with ordinary wooden shuttering cost at least twice as much as brick and generally more." In face of the general practice of monolithic cottage wall construction in this country, and of the fact that a complete wood shuttering outfit for a pair of cottages can be obtained for a few pounds, such a statement borders on the absurd. Concrete houses can compete with brick in almost any locality, and it is often found that wooden shuttering is the cheapest and best method of construction. We would recommend the author to study the lists of tender prices published in this journal to ascertain the respective costs of brick and concrete, and to realise that the tenders for the 25,000 concrete houses built last year were not accepted because they were "more than double the price of brick," but because they were the lowest.

It is regrettable that such statements should be made in an otherwise excellent volume written for the use of architects. The majority of architects are not thoroughly acquainted with the possibilities of concrete, and unless, as we hope is the case, readers of the book know more than the author about methods of concrete cottage construction and costs there is a risk that they will be for ever deterred from considering its use when they are told that concrete houses built with wooden shuttering cost twice as much as brick.

The volume is printed and bound in the excellent taste we expect from its publishers, and, as we have stated, will be extremely useful to designers and planners, but if a further edition is published we hope that inaccuracies in the references to concrete cottages will be corrected.

"Deterioration of Structures in Sea-water." (Sixth Interim Report of the Committee of the Institution of Civil Engineers.)

(London: H.M. Stationery Office. Price 2s. net.)

THIS report, edited by Mr. P. M. Crosthwaite, B.A.I., M.Inst.C.E., and Mr. Gilbert R. Redgrave, A.Inst.C.E., deals practically entirely with the Committee's investigation into the depredations of marine borers on timber exposed to sea-water, and to the protection afforded by various paints and compounds when applied to wood and metal. The experiments at Brisbane by Mr. E. A. Cullen, M.Inst.C.E. (Engineer of Harbours and Rivers to the Queensland Government), are still proceeding, and it is reported that a further set of four reinforced concrete slabs have now been placed in position. Two of the specimens have ½-in. of cover over the steel and the other two have 1 in. of cover. One specimen of each pair has been well coated with gas tar, while the others are left as they came from the mould. The condition of these specimens is to be reported periodically.

"Einflüsse auf Beton." By Kleinlogel, Hundeschagen, and Graf.

(Berlin: W. Ernst & Son. Price 19.50 R.M.)

THERE are certain problems in concrete construction which are but slightly treated in most text-books in the English language and yet are of the utmost importance to the engineer. One of these is the action of some particular chemical on concrete. Is it injurious? If so, what method can be adopted to prevent destruction of the concrete? In most text-books one finds this problem untreated, generalised upon, or at best one is referred to a periodical which may be difficult to procure.

This book is a compilation of articles on the action of chemicals, storage, air, water, etc., on concrete. The acting substances are arranged in alphabetical order, and in each paragraph are given (1) the chemical action of the substance, (2) results of experiments, (3) accounts of experiences in practice, and (4) methods, where necessary, of protecting the concrete. A large number of the articles are of German origin, e.g. replies to questions addressed to *Beton u. Eisen*, and many references are made to Abram's experiments in America. A notable omission in the article on cements is Bied's paper, "Les ciments à haute teneur eu alumine" (1913).

Under the heading "Pollution of Sand by Organic Materials" are given the results of tests at the Norwegian Technical High School, which are little known in this country. Briefly these are as follows: (1) Sand polluted by humic acid causes very decided decreases in the strength, the decreases being greater as the concrete is leaner and fresher; (2) sand may be improved by neutralisation of the acid by free exposure to dry air; (3) washing is of little use, as the acid is difficultly soluble; (4) washing with milk of lime or the addition of lime neutralises the acid; (5) the strength at seven days is the best standard for examining sand. Professor Svenson of Copenhagen has pointed out that 1 per cent. of humic acid makes any sand useless.

An approximate summary of this book shows that the following are, or may be dangerous to concrete, unless it is protected in some way:

Acids.—Sulphuric, nitric, hydrochloric phosphoric, acetic, carbonic, carbolic, humic.

Fatty acids and oils.—Linseed, palm, rape, etc.

Sulphates.—Magnesium sulphate (in sea-water), copper pyrites, etc.

Magnesium chloride,

Sugar and fruit juices.

Oxalic acid is almost harmless, as are the organic compounds known as the paraffins and mineral oils.

This reference book is illustrated by some excellent blocks and can be highly recommended to engineers with a knowledge of German.—W. S. G.

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

Foundations.

Question.—A building is to be erected on a very weak foundation, and a level raft is suggested which is also to form the ground floor. I shall be obliged if you will indicate the method of calculating the stress distribution in the slab caused by the walls of the building resting thereon, the ordinary floor load, and the weight of the slab. Should the whole of this be treated as an evenly distributed load over the whole site and the slab designed as an inverted floor slab to resist the earth pressure due to this load, the walls of the building being considered as the abutments of the slab?—H. J. D.

Answer.—The raft should, of course, be treated as stated, as an inverted floor, noting, however, that as the ordinary floor load and the weight of the slab rest directly upon the soil they must not be taken into account in the calculation of bending moments.

Whether the remainder should be treated as an evenly distributed load for the whole site depends upon the carrying capacity of the soil. If the soil is so poor that the building will settle as a whole by an amount exceeding the deflection of the raft, then this would certainly be beyond the safe distribution. If, on the other hand, the soil will safely carry that settlement (a load greater than the average stress), then it is justifiable to consider the stress on the soil greater immediately under the walls than the centre, which, of course, reduces the bending moment on the raft. The extent to which this is permissible or advisable in any particular case is a matter for the judgment of the engineer.—O. F.

Bridge Design.

Question.—Would you be good enough to explain the best method of obtaining the pressure due to (1) the earth backing, (2) the surcharge, and (3) a rolling load coming over a bridge abutment as sketched.

Assume the values,

Wt. of road materials = 125 lbs./ft.^{3}
,, ,, filling ,, = 100 ,,

(*a*) *Earth pressure due to filling.*—Rankine's formula is used and resultant horizontal thrust is

$$\frac{100 \times 17^2}{2}\left(\frac{1 - \sin\varphi}{1 + \sin\varphi}\right)$$

This acts $\frac{17'}{3}$ from the original earth level.

(*b*) *Pressure due to surcharge and rolling load.*—If we assume the M.O.T. standard loading the maximum load will be (with a 50 per cent. impact factor) due to 2 No. 11T. wheels 1 ft. apart. This load is considered to spread through 45 degrees through the depth h_1 (2 ft.).

At road level, spread area of load = (2 ft. + 2 ft. + 1 ft.) × 3 in.

At deck level, spread area of load =(5 ft. + 4 ft.) × (3 in. + 4 ft.) = 38·25 sq. ft.

∴ Intensity of loading

$$= \frac{22 \times 2240}{38\cdot25} \text{ lbs. per sq. ft.}$$

= 1290 lbs. per sq. ft.

∴ Equivalent total surcharge

$$= \frac{1290}{100} + 2 \times \frac{125}{100} \text{ ft.}$$

= 15·4 ft.

∴ According to Rankine's theory intensity of outward pressure on wall

$$= 15\cdot4 \times 100 \left(\frac{1 - \sin\varphi}{1 + \sin\varphi}\right) \text{ lbs. per sq. ft.}$$

This pressure acts uniformly over the wall.

∴ Total outward pressure

$$= 15\cdot4 \times 100 \left(\frac{1 - \sin\varphi}{1 + \sin\varphi}\right) 20 \text{ lbs.}$$

This acts 10 ft. from base of wall.

This method gives results for a high wall which appear to be excessive.

It would seem reasonable to consider that the rolling load is further distributed in the filling, at, say, an angle of 60 degrees.

Has any formula been evolved which takes this distribution into account?

S. H.

ANSWER. — The calculation for the pressure under heading (1) due to the earth backing is correct, except that the height should be taken as at least 20 ft. and should really be taken as the height from deck level to the bottom of the foundation slab, which apparently would be something more than 20 ft., and this dimension should be substituted for the figure of 17 which is used. The earth inside the bottom having a height $h_2 = 3$ ft. has only a very small effect in countering this pressure.

To this, however, should be added under heading (2), being the surcharge, a pressure at the rate of 200 lbs. per sq. ft. (being the weight of 2 ft. of earth surcharge) multiplied by the Rankine factor $\left(\frac{1 - \sin\varphi}{1 + \sin\varphi}\right)$.

The pressure due to the rolling load, under heading (3), can be treated as our correspondent has in fact treated it for arriving at the possible pressure per square foot at the top of the abutment, but this pressure will continue to distribute itself in a downward direction, and we can continue to reduce this, taking distribution at an angle of 45 degrees so that at the bottom of the wall it would have a comparatively small effect. When we get below a certain depth we get inside the lines at 45 degrees from the next wheels, and this pressure will therefore have to be added. In fact, when we get somewhere near the bottom of the wall we find that at this depth and beyond it the effect of the wheels is equivalent to an additional surcharge of somewhere round about 2 cwts. per sq. ft., and can be so treated as if it came under heading (2).—O. F.

Concrete Pipes.

QUESTION.—We are anxious to have some up-to-date information in regard to the life and usefulness of cement and concrete pipes for drainage and sewage purposes. We shall be glad if you can inform us of any suitable books or literature containing the latest information on this subject so that we may go into the matter.—B. C.

ANSWER.—There is no doubt whatever as to the efficiency of concrete sewers and drain pipes. Thousands of miles of such pipes are laid every year.

As to their life, "Concrete and Constructional Engineering" for June, 1922, mentions concrete pipes which have been excavated and found to be in excellent condition after forty years' use.

In "Concrete and Constructional Engineering" for March, 1923, is printed a letter from the Borough Engineer of Luton in which he states that on inspecting a concrete sewer laid eleven years previously he found it in as good condition as when laid: this pipe carries 3,000,000 gallons of sewage a day pumped at a head of 75 ft.

In "Concrete and Constructional Engineering" for November, 1923, there is a complete specification for the design and construction of every known type of concrete sewer pipe. This is the standard specification of the American Concrete Institute.

On the question of the ability of cement to resist the action of sewage, we might point out that even in brick sewers Portland cement is used in the mortar.

Sieves for Grading.

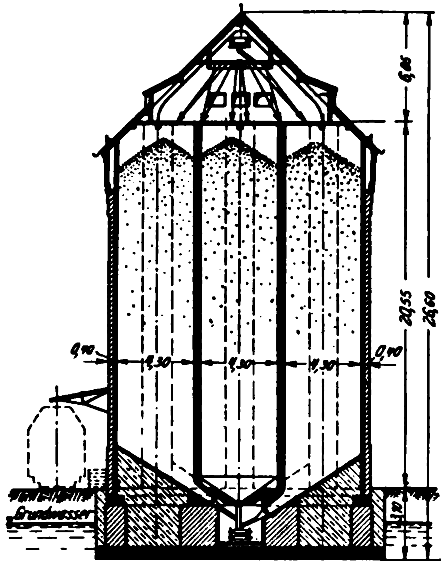
QUESTION.—Can you inform me if sieve sets as described in A. E. Wynn's articles on "Controlling the Manufacture of Concrete to obtain Uniformity of Strength," and specifically referred to on p. 487 of the current volume of "Concrete and Constructional Engineering," are obtainable in England, and from whom?—H. B.

ANSWER.—So far as we have been able to ascertain the sieves necessary for determining the fineness modulus of aggregate are not obtainable in this country, and can only be got from the American firm whose name is given in the article.

Reinforced Concrete Grain Silos.

A GRAIN silo with a capacity of 300 wagon-loads has recently been erected at Budapest in order to complete the extension of a milling plant erected in 1918.

According to "Beton u. Eisen," the battery of silos consists of three rows of four silos each, with a central conveyor. As the allowable soil-pressure on the continuous-slab foundation is less than 2 tons per sq. ft. the height of each silo is limited to about 70 ft. The internal diameter of each compartment is 14 ft., with a capacity of about 22 wagons each. The additional capacity, to make up the total of 300 wagons, is obtained from the intercellular spaces.



Cross Section C—D.

To cope with the possibly injurious effects due to temperature there is an external lining of brickwork bonded by steel to the reinforced concrete walls of the silos.

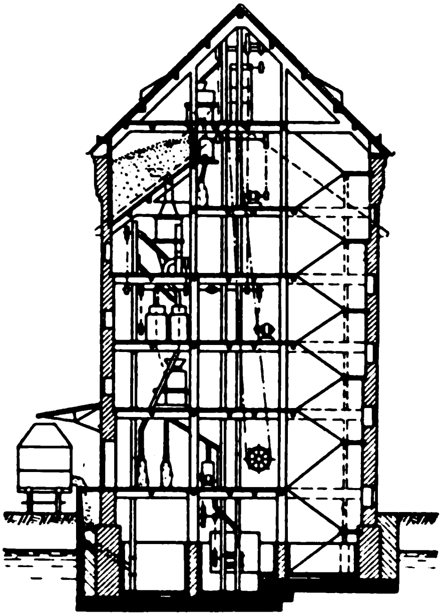
The roof is carried by means of two-hinged rigid frames supported at the points of intersection of the cells. The distribution apparatus is supported from the middle of the roof and along both sides and one end are provided the lighting and ventilating openings. In order to diminish the risk of fire the gable-end nearer the store is closed by a fire-resisting wall.

Koenen's method of calculation was used in the design with the following assumptions:

Density of grain = w = 50 lbs. per cu. ft.;

Angle of friction between concrete and filling = $\varphi = 25°$;

Angle of friction between grain and grain = $\varphi = 25°$;



Cross Section E—F.

(Longitudinal Section on p. 706.)

Hence the maximum side pressure is

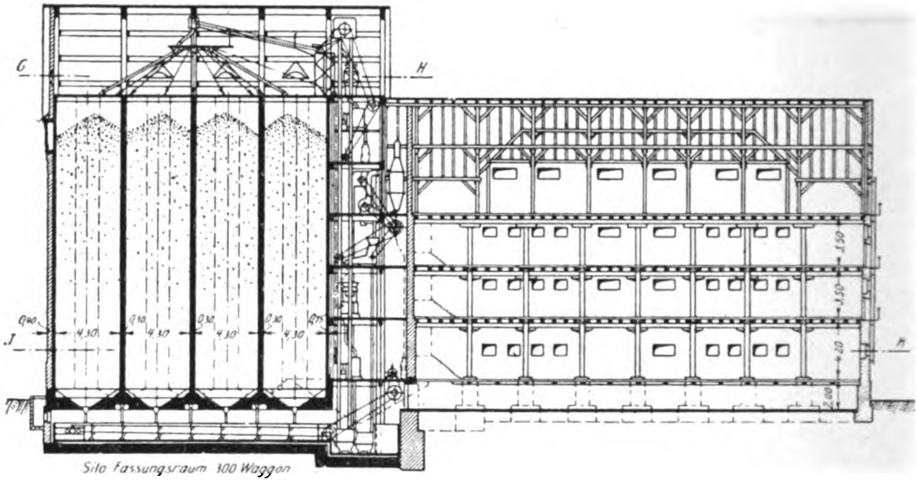
$$p_{\max.} = \frac{w}{\tan\varphi_1 \times \frac{u}{F}} = 379 \text{ lbs. per sq. ft.}$$

And the maximum pressure on the bottom is

$$q_{\max.} = \frac{p_{\max.}}{\tan^2\left(45° - \frac{\varphi}{2}\right)} = 943 \text{ lbs. per sq. ft.}$$

Maximum tension in wall (mean diameter = 14·59 ft.) is 4·54 tons. Allowable stress in steel was taken as 14,400 lbs. per sq. in.

The building work was carried out by Pittel and Brausewetter A.G., Budapest, to the design of Herr W. Obrist.—W.S.G.



Reinforced Concrete Grain Silo.—Longitudinal Section.
(*See p.* 705).

Public Works, Roads and Transport Congress and Exhibition.

NOVEMBER 1927.

PAPERS

Competition for the Award of Prizes.

The Congress Organizing Committee have decided to offer the following prizes for Papers which are submitted for discussion at the Congress to be held in November, 1927:—

1st Prize—Gold Medal and £50.
2nd Prize—Silver Medal and £25.
3rd Prize—Bronze Medal and £10.

The competition is open without restriction of nationality.

The subject of each Paper must be one which falls within the services covered by the Congress, that is to say:—Highways and Bridges, Water Supply, Sewerage and Sewage Disposal, Cleansing, Gas, Electricity, Housing and Town Planning, Tramways and Light Railways, Agriculture (Small Holdings, Land Drainage, Land Reclamation and Agricultural Education), and Local Government Organization.

Papers must be submitted not later than January 17, 1927.

Application for the rules of the competition must be made to the Hon. Secretary, Public Works, Roads and Transport Congress, 84 Eccleston Square, London, S.W.1, from whom more detailed information as regards the subjects for Papers may also be obtained.

Papers may be submitted for discussion at the Congress without being entered for competition. Such papers should be clearly marked "Not for competition."

APPOINTMENT WANTED.

REINFORCED Concrete Junior Draughtsman and Designer available almost immediately. Excellent references. Passed Sections A and B of the A.M.Inst.C.E. Examinations. Apply: J. HARRIS, 12 Jasmine Place, Aberdeen.

Pre-cast Concrete Arches in Railway Electrification.

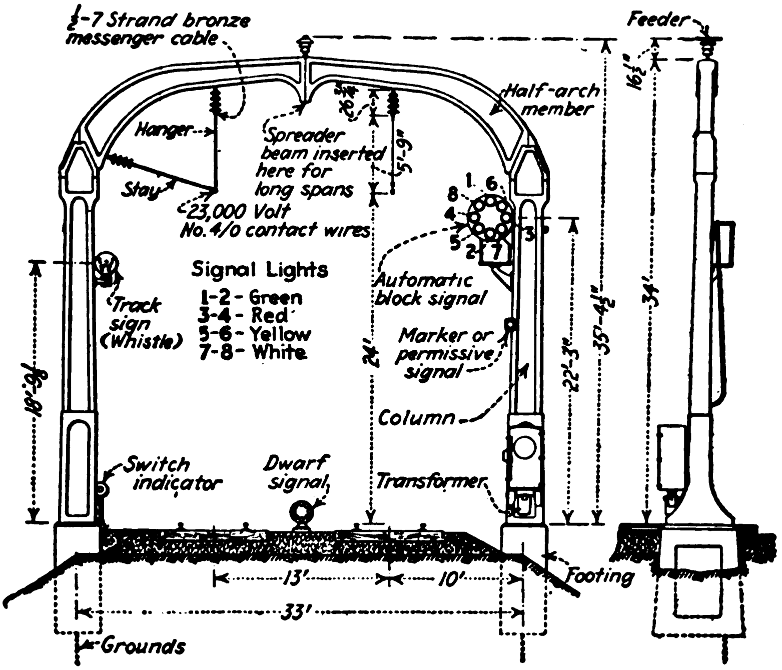
A NOVEL structural feature introduced in the electrification of the Detroit, Toledo & Ironton R.R. at Detroit, is the use of reinforced concrete arched bridges or spans to carry the overhead wires, these taking the place of the usual structural steel bridges or steel poles.

The arched spans are built of pre-cast concrete members of H-section. For the normal double-track spans there are two side columns and two arch segments, with a spacing of 33 ft. centre to centre of columns and a height of 34 ft. above the top of the rail. Where additional tracks require longer spans, a horizontal spreader beam is placed between the arch segments. The arches are spaced about 300 ft. apart. Those used to carry signals, as shown by the accompanying drawing, have smooth surfaces for the attachments and have enclosed conduits.

A plant for manufacturing the concrete units has been established, with a daily capacity of 22 members. Reinforcing rods are sandblasted, bent to shape and moved mechanically to platforms where they are assembled in skeletons which are spot-welded together, thus eliminating the use of tie wires. Forms with the reinforcement secured in place are placed on flat cars and taken to the concreting plant; after standing 24 hours in the yard, the forms are stripped and a coat of cement grout applied to the concrete.

The units are then moved first to a curing oven where they are steamed at 90 to 120 deg. for 24 hours, and then for a similar period to a drying oven of about the same temperature. Small trucks on rails then carry the units to the storage yard, where they are held for at least 18 days, after which locomotive cranes load the units on railroad cars by means of rubber-faced tongs attached to a swing beam on the crane hoist. Columns weigh about 5½ tons and the half-arches about 2 tons each.

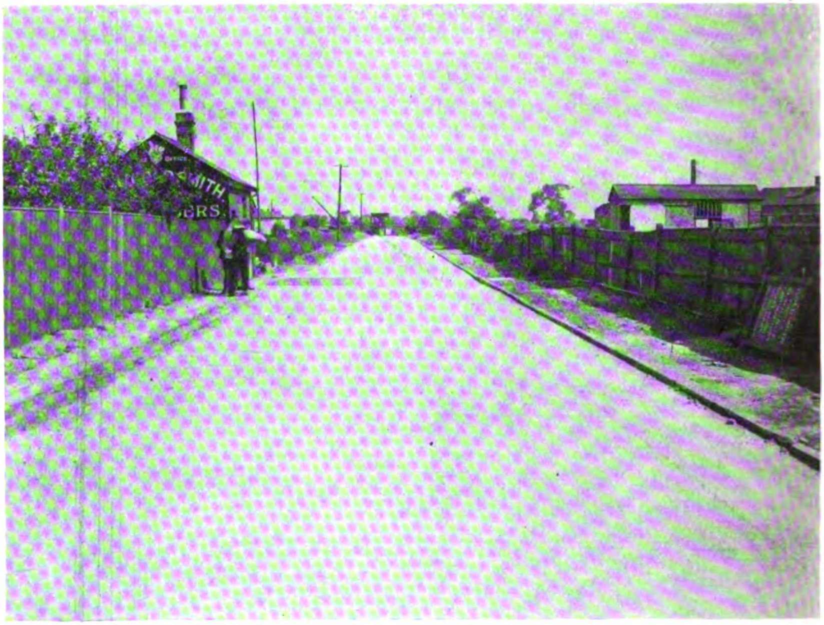
One gang of men made the excavations and set the anchor bolts, electric cables and reinforcing. Another gang poured the concrete, which was left to set for 24 hours before removing the forms and



Concrete Arches for Railway Electrification.

then for at least five days before placing the columns. With a train load of columns on one track and a locomotive crane on the other track, the columns were swung into position and set over the projecting anchor bolts. A 2-in. space was left for steel wedges to plumb the column, after which the space was packed with cement grout.

Arch members were handled on a similar train. For an ordinary span, the two members were assembled and bolted together on a car having a working platform, the completed unit being then set in place by a locomotive crane and bolted to the columns. For long spans having the spreader or extension beam at the middle, one half-arch was set in place on a column, bolted up, and supported by a falsework bent. The extension beam was bolted to the other half-arch, and this unit was swung into place, while men on the falsework bolted the spreader to the first half-arch. Finally, the messenger and trolley wires were strung by a work train having flat cars for reels of wires and box cars on which was a high platform or trestle for the workmen.



Reinforced Concrete Works Road at Dartford, Kent.

[This all-concrete road was laid at the works of Messrs. E. J. & W. Goldsmith, Ltd., at Dartford, in May and June this year, by Messrs. Chittenden & Simmons, Ltd. It is 6 in. thick, reinforced with B. R. C. Fabric.]

CONCRETE AND CONSTRUCTIONAL ENGINEERING says:—

"We congratulate the author on having prepared a thoroughly useful work on the subject. The use of influence diagrams figures largely in the work in a thoroughly practical manner, and copious examples are given both by photographs and by clear sketches which raise the value of the work considerably."

REINFORCED CONCRETE BRIDGES

The Practical Design of Modern Reinforced Concrete Bridges, including Notes on Temperature and Shrinkage Effects.

By W. L. SCOTT, Assoc.M.Inst. Civil Engineers, Chief Engineer Considère Constructions, Ltd.

Royal 8vo. Cloth. 220 Pages. 124 Diagrams. 22 Photographic Plates. Price **42s.** *net.*

CONTENTS:—Introduction—Loading and Wind Pressure—Temperature and Shrinkage Effects—Influence Lines—Arch Bridges—Girder Bridges—Bowa Ring Girder Bridges—Temporary and Permanent Hinges—Foundations and Abutments—Description of Bridges—Specification of a Reinforced Concrete Bridge.

CROSBY LOCKWOOD & SON, STATIONERS' HALL COURT, E.C.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	6
Thames ballast	„	10	6
Broken brick (¾ in.)	„	11	6
Best British Portland Cement	per ton 58s. to	63	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	„ 100s. to	105	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £20 „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
⁷⁄₁₆ in. to ½ in. Rounds	„	10	9
⅜ in. Rounds	„	11	0
¼ in. Rounds	„	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(*Based on Contracts up to £2,000.*)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

		s.	d.
Do. do. in foundation	per foot cube	1	11
Do. do. in columns	„ „	2	1
Do. do. in beams	„ „	2	3
Do. do. in floor slabs 4 in. thick	per yard super	6	0
Do. do. in floor slabs 5 in. thick	„ „	7	6
Do. do. in floor slabs 6 in. thick	„ „	9	0
Do. do. in floor slabs 7 in. thick	„ „	10	6
Do. do. in walls 6 in. thick	„ „	8	8

(*Add for hoisting* 3s. 6d. *per yard cube above ground-floor level.* *Add for* "*Ferrocrete*" 1s. 10d. *per yard cube.*)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
„ ⁷⁄₁₆ in. to ½ in.	„	21	6
„ ⅝ in. to 2⅞ in.	„	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	„ „	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	„ „	1	1½
Do. do. as last, in narrow widths	„ „	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	„ „	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

ABERDEEN.—*Concrete Bathing Boxes.*—The T.C. proposes to spend £2,500 on the construction of 100 reinforced concrete bathing boxes.

ANDOVER.—*Houses.*—The T.C. proposes to build 24 houses.

BALCOMBE.—*Reservoir.*—A reservoir is to be constructed at the Balcombe waterworks. The cost is estimated at £4,700.

BOLTON.—*Houses.*—The Corporation has instructed the Borough Engineer to prepare plans for the erection of 300 houses on the Moorfield estate.

BONHILL.—*Houses.*—The Western District Committee has recommended the Dumbarton C.C. to erect 152 houses at Bonhill.

BOSTON. — *Houses.* — The T.C. has applied to the M.H. for sanction to borrow money for the construction of 44 houses in Tattersall Road.

BRIDLINGTON.—*Groynes.*—The T.C. has instructed the Surveyor to prepare plans for improving the groynes on the north foreshore.

BRIGG.—*Houses.*—The U.D.C. is seeking permission to borrow £16,500 for the erection of 50 houses.

BRISTOL.—*Houses.*—The Housing Committee has recommended the T.C. to apply for permission to borrow £493,500 for housing purposes.

CAMBRIDGE.—*Concrete Houses.*—The T.C. proposes to build 30 concrete houses.

CHORLEY.—*Houses.*—The T.C. has applied for sanction to borrow £33,378 for the erection of 66 houses on the Rangletts estate.

COATBRIDGE.—*Houses.*—The Housing Committee recommends the T.C. to erect 500 houses on sites at Raw Farm, Woodside Street, Cliftonville, and Barrowfield Street.

DONCASTER.—*Houses.*—The T.C. is seeking permission to borrow £34,439 for the erection of 81 houses in Eden Grove.

DUBLIN.—*Houses.*—A sum of £298,500 is to be spent on the erection of 500 houses on a site of 36 acres adjoining Kehoe Square.

FELLING.—*Houses.*—The U.D.C. is seeking permission to erect 150 houses by direct labour on the Bog House estate.

FISHGUARD. — *Road.* — The Swansea R.D.C. has prepared plans for the construction of a road from Tirdonkin railway bridge to Penygroes Road.

FLEETWOOD.—*Houses.*—A scheme is being considered for the erection of 450 houses in Poulton Road.

FRASERBURGH.—*Concrete Houses.*—The T.C. proposes to erect three blocks of concrete houses.

GT. YARMOUTH.—*Sea Wall.*—The T.C. has applied for a loan towards the construction of a sea wall from Sandown Road to Beaconsfield Road. The cost is estimated at £8,511.

GT. YARMOUTH.—*Concrete Road.*—The T.C. proposes to spend £7,600 on extending the concrete road to the west of South Denes Road.

HALIFAX.—*Road.*—The T.C. has been recommended to apply for sanction to borrow £3,470 for the construction of a road from the Booth Town housing estate to All Souls' Road.

HELSTON.—*Houses.*—The R.D.C. proposes to spend £35,000 on the construction of houses in the surrounding parishes.

HOLSWORTHY.—*Reservoir.*—The U.D.C. is considering a scheme for the construction of a reservoir. The cost is estimated at £3,150.

HURLEY. — *Reservoir.* — The Maidenhead Waterworks Co. has purchased a site at Ashley Hill, Hurley, for the construction of a reservoir.

JARROW. — *Houses.* — The T.C. has applied to the M.H. for sanction to erect 100 houses on the Onkton estate.

LOUGHBOROUGH.—*Houses.*—The T.C. is seeking permission to borrow £51,760 for the erection of 100 houses to be erected by Messrs. Bosworth & Lowe, of Nottingham.

LOWESTOFT. — *Concrete Piling.* — The T.C. proposes to spend £2,050 on reinforced concrete piling work in connection with the construction of a groyne.

MALVERN.—*Concrete Road.*—A sum of £14,150 is to be spent on the reconstruction of St. Andrew's and Court Roads in reinforced concrete.

MANSFIELD.—*Houses.*—The Housing Committee recommends the T.C. to apply for sanction to erect 100 houses on the Ravensdale Farm estate.

MARSDEN.—*Houses.*—The U.D.C. has approached the M.H. for sanction to borrow £20,500 for the erection of 40 houses in Wood's Avenue.

MERIONETH. — *Concrete Road.* — The County Council proposes to reconstruct the Talylln Pass in reinforced concrete. The cost is estimated at £50,000.

MILNGAVIE. — *Road.* — The T.C. proposes to construct a road to the north of Graigdhu Road.

MILNROW.—*Houses.*—The U.D.C. proposes to build 48 houses on the Bosden Fold Road estate.

MOTTISFONT.—*Bridges.*—The Romsey R.D.C. is to build bridges over the River Test at Mottisfont. Mr. A. E. Farr is the contractor.

NEWQUAY.—*Houses.*—The U.D.C. has asked the M.H. for sanction to borrow money for the erection of 30 houses.

NUNEATON.—*Houses.*—A scheme is being considered for 150 houses.

PENMAENMAWR.—*Concrete Houses.*—The U.D.C. is to erect three concrete houses in Treforris Road.

POOLE.—*Houses.*—The T.C. proposes to build 42 houses on the Haskell's estate.

RICHMOND (SURREY). — *Houses.* — The T.C. has applied for sanction to borrow £35,500 for the erection of 63 houses on the Manor Road estate.

RICKMANSWORTH. — *Houses.* — The U.D.C. is inquiring into a scheme for the erection of 82 houses near the Croxley Green Railway Station.

ROTHWELL HAIG. — *Houses.* — The U.D.C. is to erect 42 houses.

RUTHERGLEN. — *Road.* — A sum of £16,360 is to be spent on the construction of a road off East Main Street.

SEGHILL. — *Houses.* — The U.D.C. is negotiating for a site on which to erect 75 houses.

SHEPTON MALLET. — *Houses.* — The U.D.C. proposes to build 30 houses.

SOWERBY BRIDGE. — *Houses.* — The U.D.C. proposes to build 50 houses on the Beech Wood housing estate.

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STAMFORD.—*Road.*—The Borough Surveyor has been instructed to prepare plans for the construction of a road to relieve the traffic on the Great North Road.

SUNDERLAND.—*Road.*—The T.C. proposes to spend £20,000 on the construction of a 60-ft. wide road from Newcastle Road to Sidecliffe Road.

SWANSEA.—*Houses.*—The T.C. has applied for permission to borrow £30,000 for housing purposes.

WELLINGBOROUGH. — *Houses.* — The R.D.C. proposes to erect 62 houses in the surrounding parishes.

WEYMOUTH.—*Houses.*—The T.C. proposes to erect 100 houses on the Westham estate.

WINDSOR.—*Houses.*—The T.C. proposes to build 138 houses on the Vale Farm estate, Clewer.

YEADON.—*Houses.*—The U.D.C. has asked the M.H. for sanction to borrow £20,000 for the construction of 40 houses on the Henshaw Lane estate.

Tenders Accepted.

CHEADLE. — *Concrete Culvert.* — The U.D.C. has accepted the tender of Messrs. W. H. Worthington, Ltd., Manchester, at £258 14*s.*, for the construction of 20 yds. of reinforced concrete culvert.

DENHOLME (YORKS). — *Concrete Flags.* —The U.D.C. has accepted the tender of Messrs. J. Smith & Sons, Denholme, at £488 7*s.* 8*d.*, for the supply of about 596 sq. yds. of concrete flags.

EDINBURGH.—*Concrete Platform.*—The Corporation has accepted the tender of Messrs. Topping & Co., 20 George Street, Edinburgh, at £202 6*s.* 3*d.* for the construction of a reinforced concrete tipping platform, together with a mass concrete foundation for a new destructor unit.

GODSTONE. — *Concrete Road.* — The R.D.C. has accepted the tender of Messrs. David Weston & Co., Ltd., for the construction of a reinforced concrete road at Tylers Green.

NORWICH.—*Concrete Factory.*—Messrs. Mullen & Lumsden have secured the contract for the erection of a reinforced concrete factory in Northumberland Street, Norwich.

SOUTHEND-ON-SEA.—*Concrete Pipes.*—The T.C. has accepted the tender of Messrs. J. Ellis & Co., Leicester, at £280, for the supply of reinforced concrete pipes.

STOCKPORT. — *Concrete Tubes.* — The T.C. has accepted the tender of Messrs. W. H. Worthington, Ltd., Manchester, at £1,614 15*s.*, for laying about 200 lineal yards of reinforced concrete tubes along the Brown House Fold Brook.

WHITEHAVEN.—*Concrete Reservoir.*—The T.C. has accepted the tender of the Border Engineering Contractors, Whitehaven, at £2,998 13*s.*, for the construction of a reinforced concrete service reservoir at Harras Moor. Other tenders submitted were: J. Leslie & Sons, £3,707 18*s.* 5*d.*; Grays Ferro-Concrete Co., Ltd., £3,429 1*s.*; Leyland Construction Co., £3,332 5*s.*; Morgan & Cleghorn, £3,142 3*s.* 2*d.*; Cumberland Reinforced Concrete Construction & Artificial Stone Co., £3,026 4*s.* 3*d.*

Recent Patent Applications.

255,509.—T. Whiting: Shuttering for concrete walls.

255,575.—L. White: Concrete building construction.

255,596.—Concrete Ltd. and C. B. Mathews: Concrete blocks.

255,627.—R. J. Lyne and C. A. Midgley: Concrete construction.

256,014.—H. Stehmann: Revolving tubular kiln for burning cement, magnesite and lime.

256,058.—D. Cunningham: Concrete kerbs.

256,105.—Dr. F. B. Dehn: Retaining-wall structures.

256,150.—A. Wolfsholz: Concrete piles.

256,411.—W. D. McLaren, G. M. Welsh and J. C. Johnstone: Moulding concrete.

256,695.—A. Francis: Shuttering for concrete buildings.

Trade Notices.

Batcher Plants and Inundators.—In our August number we illustrated and described the "batcher" plants and inundators now being extensively used for the measurement of aggregates in the United States. These plants are manufactured by the Blaw Knox Company, whose agents in this country are Messrs. Christmas & Walters, Ltd., of Caxton House, Westminster, S.W.1.

Reinforced Concrete Warehouse at Staines.—Messrs. Huntley & Sparks inform us that their well-known "Rigifix" bolt hanger sockets and slotted inserts were used for fixing machinery and belting at the warehouse at Staines for the Linoleum Manufacturing Co., Ltd., illustrated and described in our September number.

Plan Reproduction.—We have received from Messrs. George Falkner & Sons, of 170 Deansgate, Manchester, a copy of a brochure they have issued dealing with the question of plans for deposit in Parliament and for reproduction and submission to the Ministry of Transport. The brochure, written by Mr. Percy W. Reed, gives full information on the procedure in reproducing and submitting plans accompanying applications for sanction to carry out public works.

Concrete Roads in Manchester.—On p. 638 of our September number the cost of the concrete roads at Manchester should read 7*s.* 9·82*d.* a square yard.

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CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

NOVEMBER 1926 **VOL. XXI No. 11**

TWENTY-FIRST YEAR OF PUBLICATION

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XXI. No. 11. LONDON, NOVEMBER, 1926.

EDITORIAL NOTES.

Grouting with Cement.

THE use of cement in the form of grout, i.e. cement to which sufficient water has been added to form a mixture that will readily flow, has of late years reached considerable dimensions. The fixing of holding-down bolts for machinery in brickwork or concrete foundations with liquid cement grout has been practised for many years, but the comparatively recent extension of the same principle to other purposes has now developed to a large extent, and indicates a definite advance in constructional work.

The grouting of the piers of St. Paul's Cathedral is an outstanding example on a large scale of this important development, and the strengthening of the foundations of Winchester Cathedral was an earlier example of a similar method of repair work. In cases such as these liquid cement grout is pumped through small holes bored into old masonry which is known or suspected to contain voids and to be lacking in strength. The cement grout is expected to fill the voids and thus consolidate the loose masses of stone into a monolithic whole. In other cases cement grout is pumped below foundations where additional support is needed.

The sinking of colliery shafts by the cementation method is becoming an important specialist operation, and good service has been rendered to the mining industry by this means. The object in this case is to seal the fissures in any water-bearing strata through which a shaft is being sunk so that water can no longer flow through the ground and impede the sinking operations. For this purpose cement grout is pumped into the ground through small holes and the cement finds its way under pressure into all the cracks and fissures through which water can pass, so that when setting takes place the further flow of water is prevented and the main sinking operations can be carried on in dry strata.

In the boring of oil wells sealing-off with cement grout is also an essential operation in many cases, and successful boring frequently depends upon the efficacy of the cement seal in preventing water rising with the oil to the surface.

The latest example of the application of cement grout on a large scale is in the grouting of roads. The road bed is spread with suitably graded stone and rolled dry. Cement grout, or alternatively dry cement with a copious application of water, is then brushed into the road surface, which is again rolled. The expectation in this case is that the spaces between the road stone become filled with cement which, on setting, will bind the stone into a concrete. It is not claimed that such road surface equals an orthodox concrete road, but grouted roads are said to be satisfactory for secondary roads and several successful examples are in existence.

In ordinary concrete work the use of a minimum of water is regarded as necessary for the production of strong concrete, and as the proportion of water to cement is increased the strength of the concrete decreases at a rapid rate. The importance of keeping the " water ratio " (ratio of water to cement) low is indeed one of the fundamental rules of scientific concrete-making now becoming widely adopted. Hence it is somewhat surprising that such good results are obtained with cement grout in which the " water ratio " is so far above the accepted practice, and it is probably not sufficiently recognised that the successful application of grout largely depends upon the removal of the surplus water which the grout contains. Cement grout may contain 50 per cent. or more of water, which implies that the grout is composed of about 60 per cent. of binding material and 40 per cent. of water which is only a hindrance to the development of strength. If the water remains in the grout after setting, the latter can only set as a honeycomb in which the cells are filled with water ; or if the water is ultimately dried out then the honeycomb has its cells filled with air. Apart from any scientific considerations it is a common-sense conclusion that cement mixed with far more water than can be absorbed must produce a weak mixture. An example of this is given by the following results of tests :—

7 Days' Tensile Tests with Neat Cement.

(*a*) With 23 per cent. water (min. to produce paste) 750 lbs. per sq. in.
(*b*) „ 40 „ „ „ („ „ „ grout) 450 „ „ „ „

It will be obvious that the excellent results obtained with grout in practice are not the result of the reduced strength shown by these tests, and it is a reasonable deduction that the successful use of grout depends upon the removal of the excess water either by absorption, settlement, filtration, or evaporation.

Of these four factors which are useful, if not essential, to the production of successful results from the application of grout it is probable that absorption and settlement are the most usually operative. An experiment designed to show the increase in strength of neat cement grout obtained by removing the excess water by absorption (made by moulding test briquettes of the usual form upon an absorbent base instead of upon the usual iron plate) gives results as follows:—

Tensile Strength at 7 Days of Neat Cement.

	Lbs. per sq. in.
(*a*) Under normal conditions with 23 per cent. water . .	750
(*b*) As grout with 40 per cent. water	450
(*c*) As grout with 40 per cent. water moulded on absorbent base.	770

The strength of cement grout is thus shown to be increased by 75 per cent. and brought up to the normal strength of cement by removal of the excess water by absorption. It is probable that this process of absorption occurs frequently in practice and is the cause of the many cases of success that ensue.

In the case of oil-well sealing with cement grout, it is probable that the separation of the superfluous water by the settlement of the cement into a compact mass at the bottom of the bore is the essential to success.

Again, in the sealing-off of water-bearing strata it is not unlikely that some filtration takes place, and the unnecessary water passes away leaving the cement behind to set and harden in a normal manner. In the majority of cases where cement grout is used these means of eliminating superfluous water occur naturally and are taken as a matter of course, but there must be some cases where the necessary circumstances do not exist and it is probable that these are less successful.

In the case of road grouting the excess water may be able to flow away if there is a gradient, or to percolate through a porous sub-grade, and so far as possible it would be a reasonable precaution to provide means for the water to get away.

Various opinions are held as to the qualities of cement suitable for grouting. Quick-setting cement has been specified in some cases in the hope that the grout (which will inevitably be slow hardening, unless the unnecessary water is removed) will have its hardening expedited. This has probably been responsible for some failures arising from the " killing " and disturbance of the initial set of the cement, because the preparation and application of grout cannot easily be completed within the period of the initial set of a quick-setting cement. Quick hardening of grout will be most readily obtained by removal of excess water.

Another quality of the cement which has come under discussion is its fineness. If the grout acquires its strength by the settlement procedure referred to, then a coarsely-ground cement is to be preferred, but if in the sealing of strata the interstices and voids are of microscopic dimensions, then finely-ground cement should be more effective.

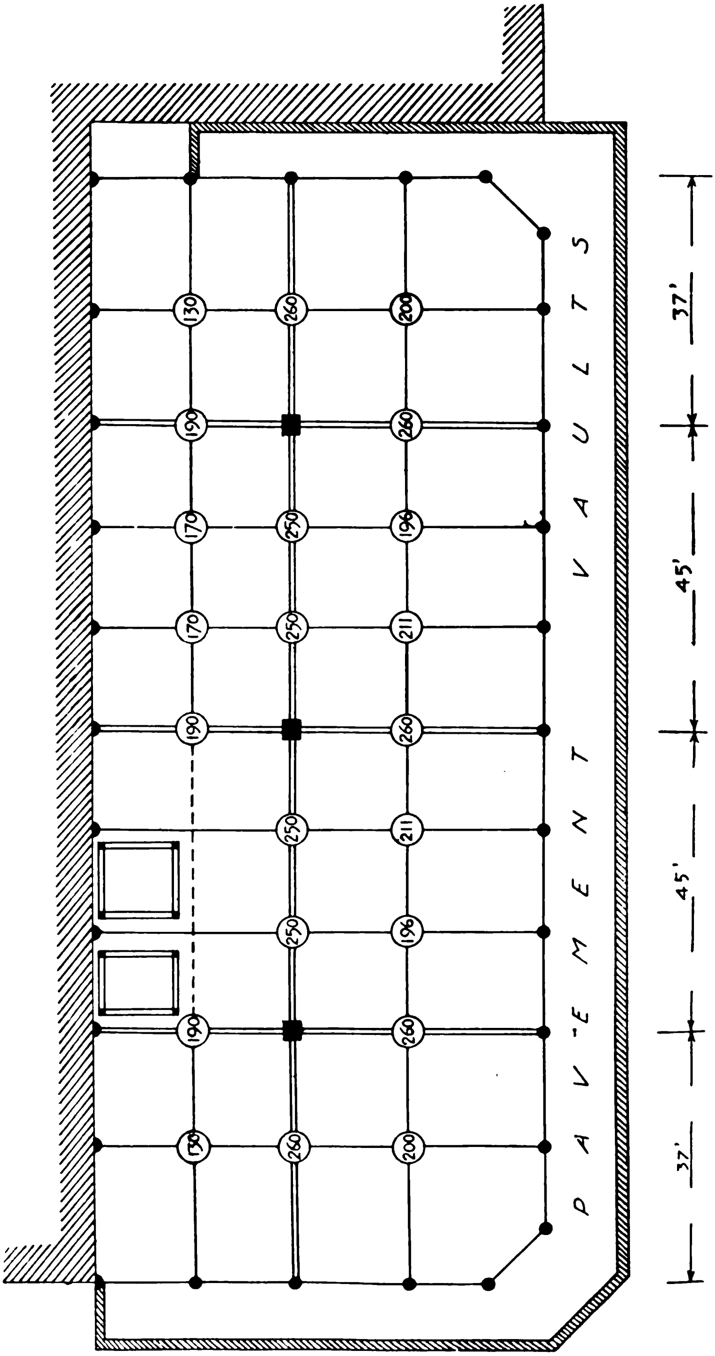


Fig. 1.—Loading Plan. *(See p. 717.)*

An Unusual Reinforced Concrete Structure.

250-TON POINT LOADS CARRIED ON 45-FT. SPAN BEAMS.

A GOOD example of the constructional use of reinforced concrete in circumstances where structural steel would have been, if not impossible under the circumstances prevailing, at any rate far more costly and difficult, is to be found in the premises now in course of erection in Stamford Street, Waterloo, for the Cornwall Press.

The basement of the building is to be used for printing purposes, and one of the requirements in regard to the installation of heavy printing machines is the provision of as large unbroken spaces as possible, necessitating as few internal piers as possible. The spacing of the latter therefore is kept as wide as practicable, varying from about 37 ft. to 45 ft., according to the architectural arrangement of the building. It is not, however, intended to carry the wide spacing up through the whole of the eight stories of the building, which is to be used for warehouse and office purposes, and the basement ceiling therefore has to provide for the carrying of the loads from the upper floors as point loads from piers spaced at the more usual distance of from 15 ft. to 20 ft.

The upper floors are of the usual type of construction and present no particular features of interest structurally ; the pier loads at ground floor level, from the accumulated floor loads, amount to 200 to 250 tons on each pier, and some of the beams in the basement ceiling are therefore called upon to carry the somewhat unusual loading of two point loads of 250 tons each on a span of 45 ft. As the amount of headroom in the basement is an important consideration, the depth of the beams had to be kept within reasonable limits, nowhere exceeding 5 ft. total, and it will be seen that in meeting this condition reinforced concrete has the immense advantage of continuity over steel construction.

A glance at *Fig.* 1, showing a diagrammatic loading plan of the basement, will at once make this apparent. The double lines indicate the main beams taking their bearings on the internal piers (black squares), while the single lines show the

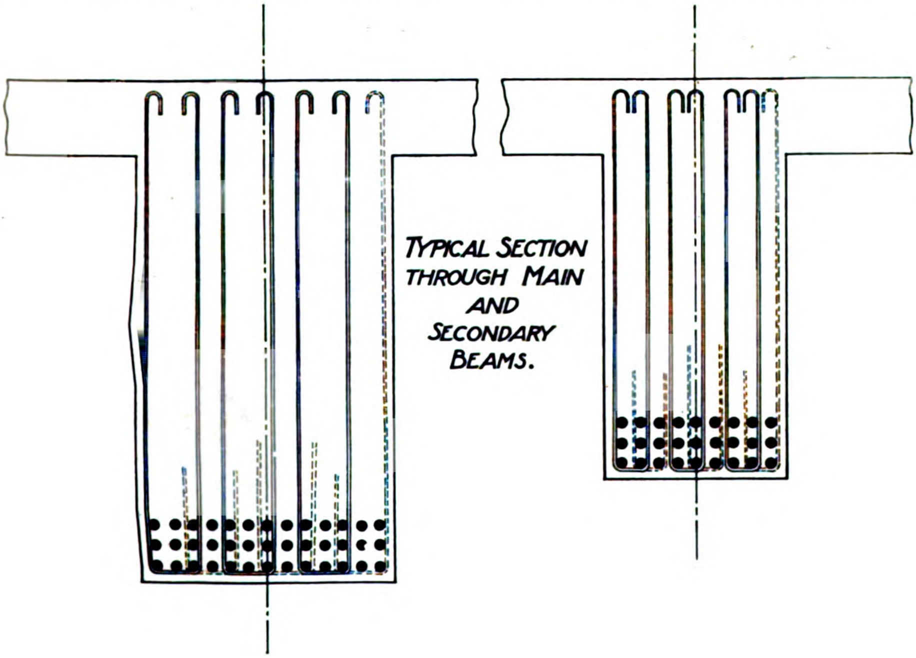


Fig. 3.—Sections of Beams.

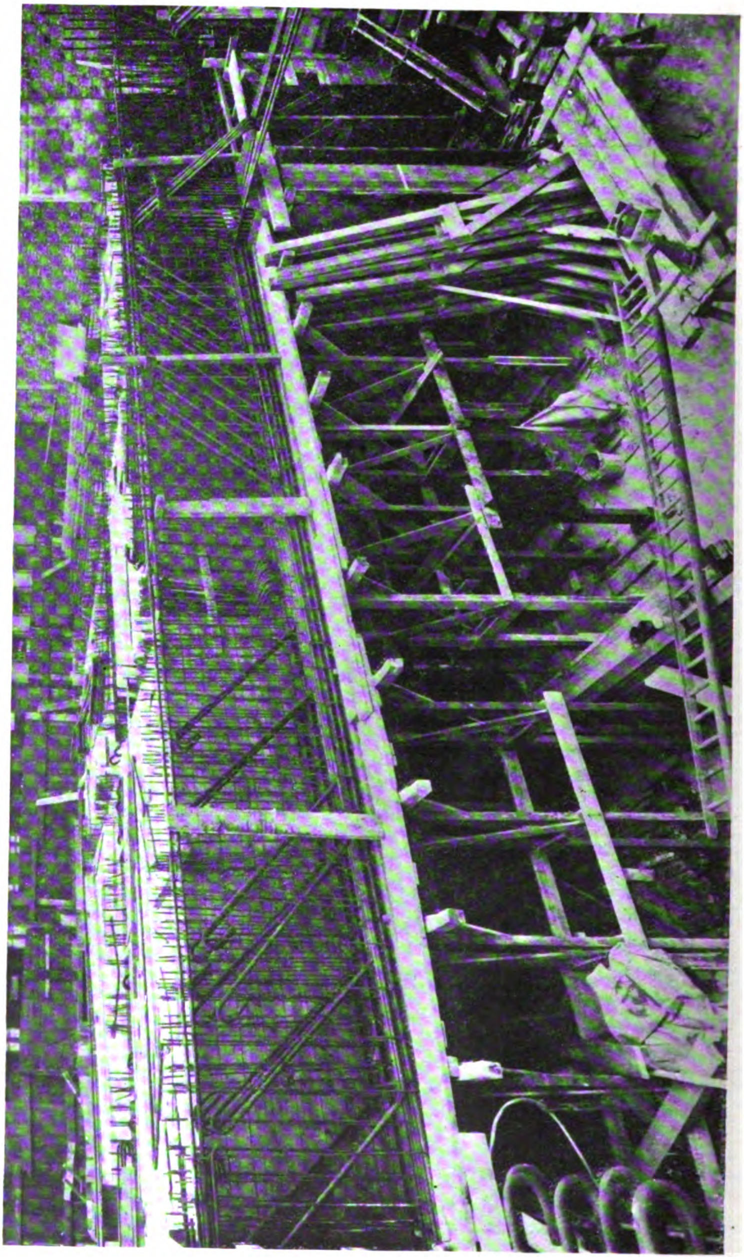


Fig. 4.—Beam under Construction.

arrangement of secondary beams. At each point of intersection a point load from the superstructure is taken, the magnitude of which in tons is indicated by the figures within the circles.

It will be seen that a single simply-supported girder over the 45-ft. span would have a bending moment from the point loads of 3,750 ft. tons, which would require about 120 sq. in. of steel in the top and bottom flanges. It would be nearly impossible to procure real continuity over the supports, at any rate in both directions, in a steel girder, whereas the reinforced concrete construction makes use of the continuity, not only in the beams themselves but also through the homogeneous connection with the piers. By a suitable proportioning of the dimensions and a corresponding arrangement of the reinforcement it is possible to distribute the bending moments over the beams and piers so that the former do not attain more than about half the

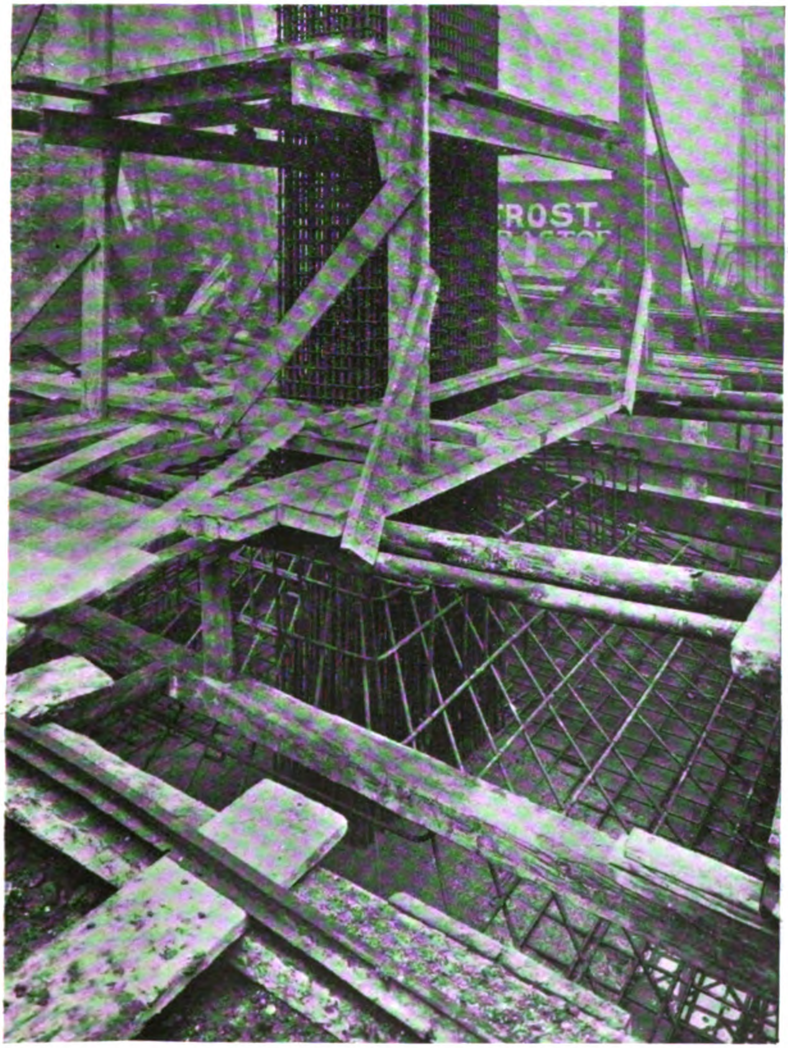


Fig. 2.—Reinforcement of Column.

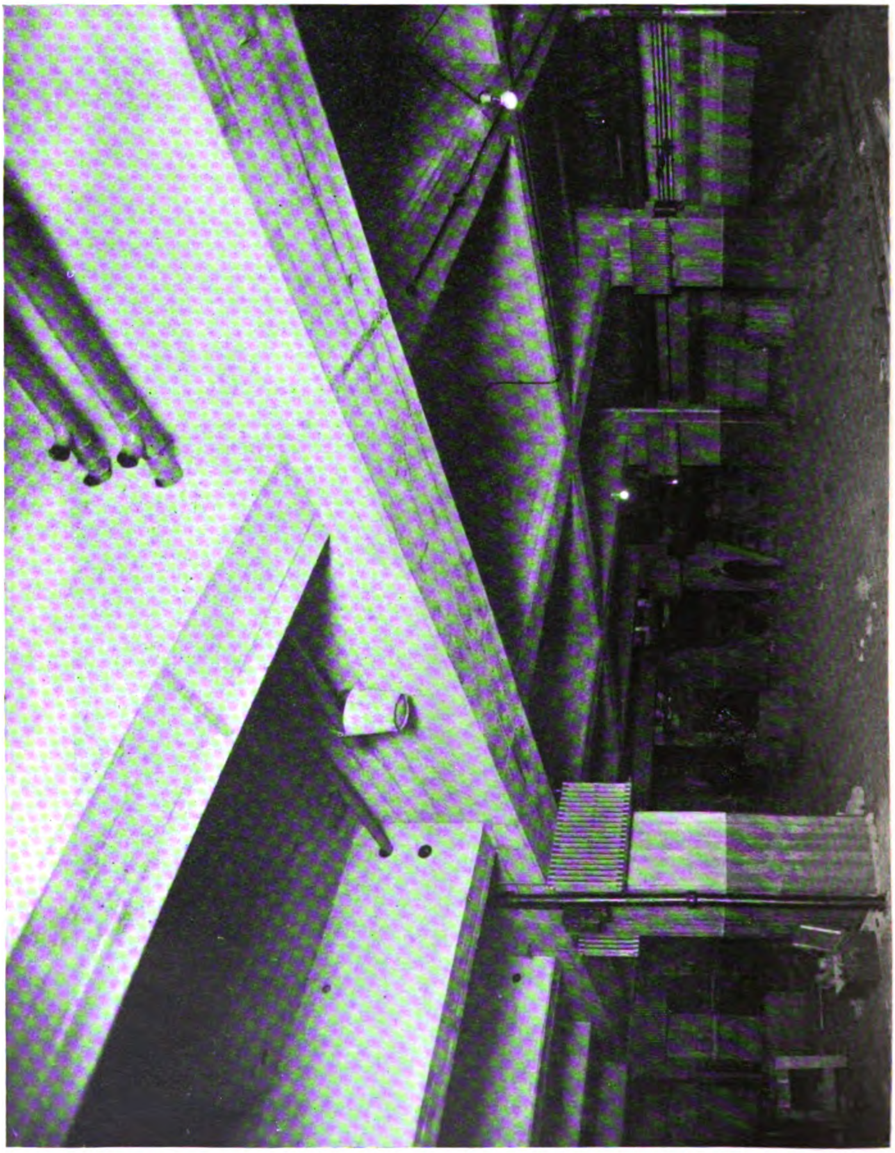


Fig. 5.—View in Basement.

values found above, and as in addition the concrete acts as compression member the saving in steel is obvious.

In disposing of the point loads from the piers the principle in the design has been to distribute the loads on the two beams at the intersection point in the proportion dictated by their relative deflections, and in this manner it has been possible to keep all the secondary beams within a depth of 4 ft. total, while all the main beams are 5 ft.

The ultimate load on the internal piers amounts to nearly 1,000 tons on each, and the foundations are taken down to a considerable depth in order to find a good ballast bed. A view of the steel work in one of the piers, with the spread foundation, is given in *Fig.* 2. Typical sections of main and secondary beams are shown in *Fig.* 3, the former having three layers of thirteen rounds, and the latter three layers of nine rounds, the bars being cranked as required to meet the shear. A photograph of the actual placing of the reinforcement for one of the beams is shown in *Fig.* 4, while a view of some beams just after the striking of the centering is given in *Fig.* 5.

It will be noticed that a number of barrels has been left in the beams to provide holes for the carrying through of heating and sprinkler pipes, cables, etc., and for providing attachments for any future fixtures or machinery that may be required to be slung from the beams; similarly the soffits of the floor panels have been liberally sprinkled with inserts for hanging bolts, so that all future needs may be met for attaching all possible kinds of fixings in the machine room.

An interesting feature in connection with the building is the vault retaining wall surrounding the premises, by means of which an uninterrupted space under the pavement, for storage or transport, is added to the basement at a small cost. The retaining wall is of the self-contained cantilever type, and is calculated for a surcharge of 4 cwts. per sq. ft. on the pavement. *Fig.* 6 gives a section through

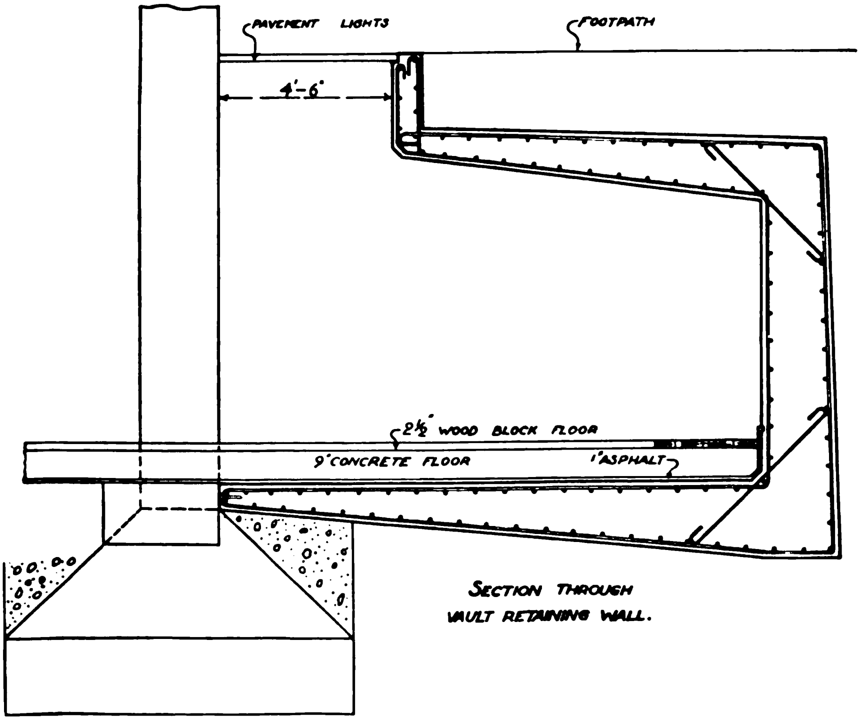


Fig. 6.—Section of Retaining Wall.

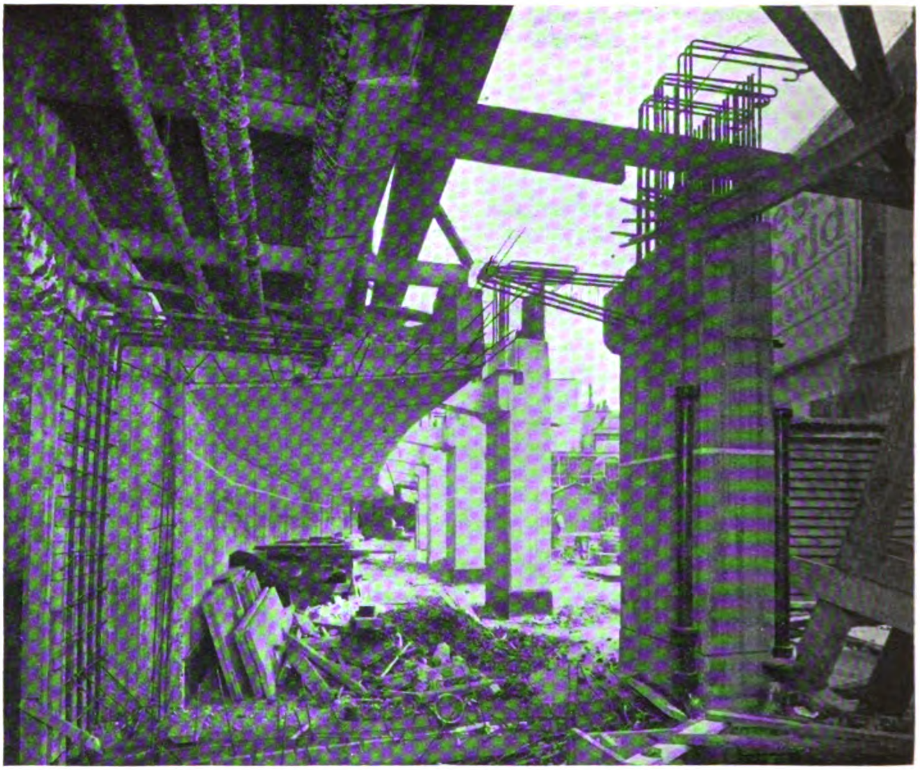


Fig. 7.—Retaining Wall During Construction.

the retaining wall, and the view in *Fig.* 7 shows a portion of it concreted; the width of the vault is about 14 ft.

The engineer for the constructional work is Mr. A. Drew, of 108 Victoria Street, S.W.1, with whom Mr. R. N. Stroyer, of Abbey House, Westminster, S.W.1, is collaborating in the design of the reinforced concrete work described above. The contractor is Mr. A. E. Frost, of Ewart Grove, N.22, whose sound knowledge of reinforced concrete construction and conscientious work is proving of great value in carrying out a difficult piece of work. Rapid-hardening Portland cement is being used for the work.

High Tension Reinforcement.

By **EWART S. ANDREWS, B.Sc. Eng., A.M.Inst.C.E.**

Introductory and Historical.

SOME twenty years ago there was considerable discussion as to the advantages or otherwise of high-tension steel for use in reinforced concrete construction; and it was then generally recognised that as the yield point stress in the steel practically corresponds to failure in a reinforced concrete beam or slab it should be permissible to use higher working stresses for high-tension steel than for ordinary mild steel.

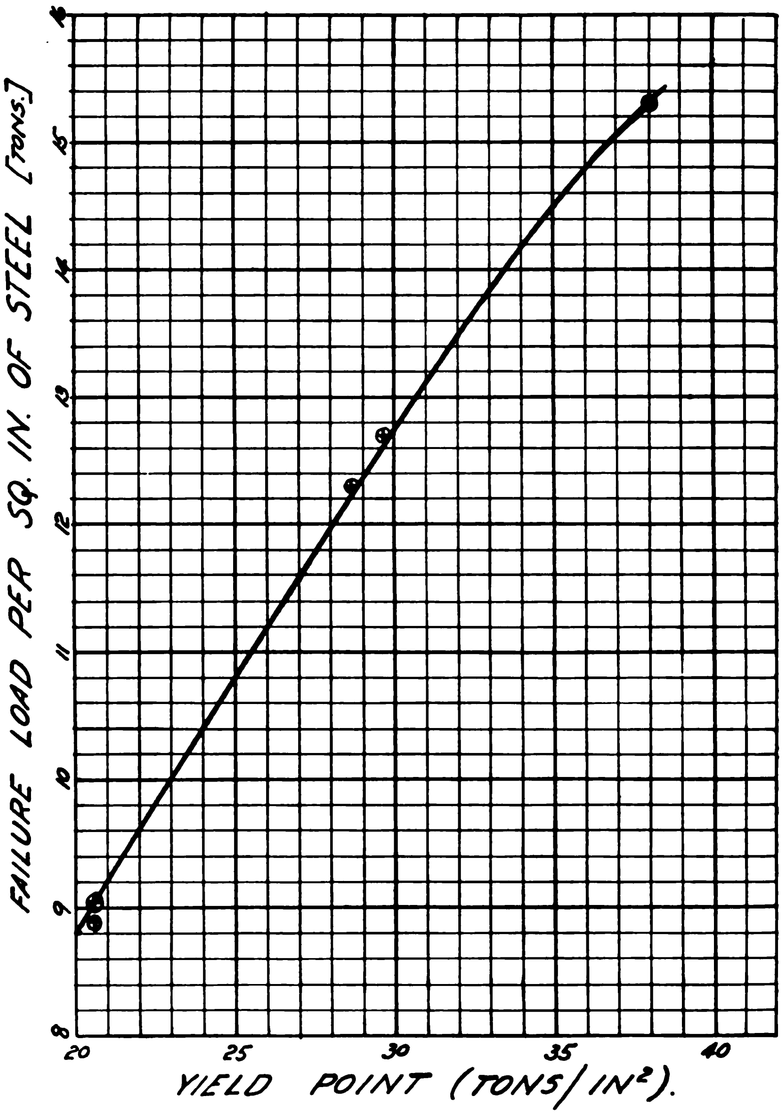
The Report of the Joint Committee on Reinforced Concrete conducted by the Royal Institute of British Architects (generally called the "R.I.B.A. report 1911") recognised this and recommended that if a stronger steel than ordinary mild steel were employed the permissible stress in the steel should be one-half the yield point stress with a maximum of 20,000 lbs. per sq. in.; this compares with 16,000 lbs. per sq. in. for mild steel.

When the London County Council Regulations were in draft they were submitted for comment to the professional institutions mentioned in the Act of 1909; these draft regulations restricted the steel to that complying with the British Standard Specification for mild steel, and fixed the stress at 16,000 lbs. per sq. in. The Concrete Institute (since become the Institution of Structural Engineers) after lengthy discussion in committees recommended that for special steels such as medium carbon steel and drawn steel wire a working stress of 20,000 lbs. per sq. in. should be permitted.

The authorities, however, did not agree with this recommendation, and the Regulations came into force in 1916 with the steel restricted in the manner set out above.

It should be noted that not only do these regulations not allow higher stress to be used for the stronger steel, but in most cases they prohibit its use. It is only by a kind of accident that medium carbon steel and drawn wire reinforcement can be used in any circumstances. This arises from the fact that the British Standard Specification states that the ultimate strength of the steel must be between 28 and 33 tons per sq. in., and that all steel must pass a certain cold bend test; there is, however, a provision that for steel under $\frac{5}{16}$ of an inch in diameter or thickness bend tests only shall be required. It thus arises that rods under $\frac{5}{16}$ of an inch in diameter may be employed although their tensile strength is not within the above limits.

The writer has always been opposed to specifying an upper limit to the tensile strength of steel provided that ductility is ensured; at a lecture which he gave some years ago he showed test results of a special steel having a very good ductility and yield point of over 45 tons per sq. in. It is true this steel was too expensive to use in concrete construction, but greater demand would soon result in lower cost and there are now available high-tension steels at reasonable cost which could be used with advantage. It is always unwise to allow regulations to hamper progress in technical development; it is possible that before long rust-resisting steels will be available at a comparatively reasonable price, and it would be very unwise to prohibit their use due to the terms of regulations made before this kind of steel was contemplated.


FAILURE LOAD PER SQ. IN. OF STEEL [TONS.]
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15
16
20
25
30
35
40
YIELD POINT (TONS/IN²).

We will now consider the arguments in favour of allowing high-tension steel to be used for reinforced concrete and for permitting higher stresses to be employed in its design.

Experimental Evidence.

The only experimental investigation into the subject with which the writer is acquainted is that conducted by the Concrete Institute some years ago. This was carried out by a Sub-Committee of the Institute—formed of some professional members and some members having a commercial interest in the subject, with Mr. H. Kempton Dyson as Chairman.

The results of the tests carried out by this Sub-Committee were given in a paper read before the Institute by Mr. Dyson in 1921 ; the writer has studied these results with some care and has collated them in a form which we will study later.

Reinforced concrete slabs of 6 in. effective depth and 21 in. width were tested by central loading on a span 10 ft. 3 in. Five kinds of steel reinforcement were employed, viz. (1) standard mild steel, (2) "shell-discard" steel—almost the only steel available during the war, (3) medium carbon indented bars, (4) twisted bar, (5) drawn wire.

Samples of these steels were tested by Mr. R. H. Stanger—a member of the Sub-Committee—and the average results are given in the table herewith.

TEST RESULTS OF REINFORCED CONCRETE SLABS.

Kind of Steel.	Area Used (sq. in.).	Test Strength of Steel. Tons per sq. in.		Failure Load (lbs.).	Failure Load. Lbs. per sq. in. of Steel.
		Yield.	Ultimate.		
Mild	·895	20·6	26·8	8,100	9,050
,, ...	·753	20·6	26·8	6,700	8,900
Shell Discard	·605	21·3	31·1	5,000	8,270
Twisted Bar	·589	28·7	36·4	7,250	12,300
Indented Bar	·589	29·7	42·6	7,450	12,700
Drawn Wire	·589	37·8	39·4	9,010	15,300

The table also gives the average load at failure—this is the added central load and does not include the dead weight of the slabs, the equivalent central loads of which were 760 lbs. These tests of the slabs were conducted at the Manchester College of Technology by the staff of the College under the charge of Mr. H. Carrington in the presence of members of the Sub-Committee.

The two sets of slabs reinforced with mild steel were designed on the usual formulæ to have stress in the steel of 16,000 lbs. per sq. in. and concrete stresses of 600 and 550 lbs. per sq. in. respectively ; the others were designed for 20,000 lbs. per sq. in. in the steel and 600 lbs. per sq. in. in the concrete.

The writer has added the end column to give a comparison for the same area of steel ; this, of course, assumes that the concrete would not have failed in compression before the steel gave way, but is no doubt justified in considering the relative values of the steels. The "shell-discard" result is included with the others because it was included in the report ; the steel was clearly, however, not of the quality intended and did not justify the design stress of 20,000 lbs. per sq. in. and will not be considered further.

It is interesting to compare the relation between the yield point strength of the steel and the failure load per square inch of steel; this is shown in the accompanying curve, in which the yield point of the steel is plotted horizontally and the failure load per square inch of steel is plotted vertically. In this diagram the "shell-discard" figures have been omitted.

From the diagram it will be seen that in these experiments the equivalent test strength of slabs for equal areas of reinforcement is almost proportional to the yield point strength of the steel, thus showing that the permissible working stresses in the steel should be much higher for steels with high yield points than for ordinary mild steel, and that if 16,000 lbs. per sq. in. is suitable for mild steel, about 20,000 lbs. per sq. in. are suitable for the twisted bar (a mild steel bar strengthened by twisting cold) and the indented bar (a bar of medium carbon steel), and about 25,000 lbs. per sq. in. are suitable for the drawn wire.

Conclusion.

It is clear from these figures that the drawn-wire reinforcement, calculated to receive a working stress 25 per cent. in excess of that used for mild steel, gave a slab that was actually stronger than that using mild steel reinforcement. It seems that further independent tests should be made under similar conditions to explore this point in greater detail.

It must be admitted that up to the present some eminent engineers have been opposed to the use of high tensile steel; the writer, while respecting their opinion, does not share their view. One argument against the use of higher stresses is that the elastic stretch of the concrete will result in fine cracks on the tension side; this is an important point in water-retaining structures, but not in ordinary floor construction. Moreover, the great increase of strength of concrete resulting from improvements in cement manufacture brings new considerations before us.

Another argument that is sometimes urged against the use of higher stresses for "worked" steels, such as drawn wire and twisted bars, is that the additional strength of such worked steels is lost if the temperature is raised sufficiently to anneal them; it is therefore stated that in the case of a serious fire the steel would lose its additional strength.

The writer's view on this point is that we should not allow possible future fires to have such a strong effect upon design. Extremely few buildings with reinforced concrete floors ever have a fire in them; in those that do the temperature is extremely unlikely to rise so high that the heat will soak through the cover sufficiently to raise the steel to the annealing temperature. The sensible course appears to be to wait until a fire has occurred; if it is so serious that it is likely to have annealed the steel, then clearly the whole building should be inspected carefully before it is allowed to go into use again.

This is a risk which a building owner should be allowed to face himself; regulations based upon fire considerations should only be concerned with the safety of the inmates during the fire.

Rapid Concrete Construction.

THE new factory for Messrs. Wrigley, now in course of construction at Wembley, is of interest from many points of view. It is a model of the latest word in American factory design in construction, arrangement, and size, with an elevation of pure English conception. The owners, with great experience of factory construction, came over here with their minds made up because they knew what served their purpose best.

Anyone who is concerned with the housing of manufacturing plant will be interested to know the points which were foremost in the owners' mind. It had to be a multi-story building ; it had to be in reinforced concrete. They had passed the stage of doubt as to whether steelwork rendered fireproof was cheaper and speedier in erection—they knew that reinforced concrete if rightly handled is the most economical and quickest to construct. They also knew that the cheapest and quickest method for such a building was the mushroom type of construction.

For the progressive mind the fact that these views are held in that part of the world where efficiency counts for everything must be of interest, but it is a little disturbing to realise that this method of designing is almost prohibited in those districts in England where reinforced concrete regulations are in force.

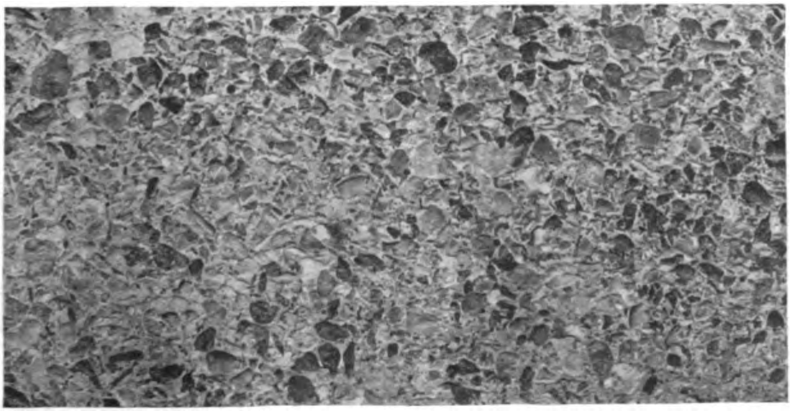
The owners themselves set the example of speed. Within three weeks of their arrival in London they signed a contract on completed drawings and bills of quantities, which was very much to the credit of the architects and engineers, a fact which the owners acknowledged when they stated that they could not have done it quicker in the States.

The design was made for speed, making it possible for the centering to be repeated. A novel feature of the centering is the great amount of steel forms used and the elimination of wooden propping by the use of easily assembled constructional steelwork, a new feature brought out by the contractors.

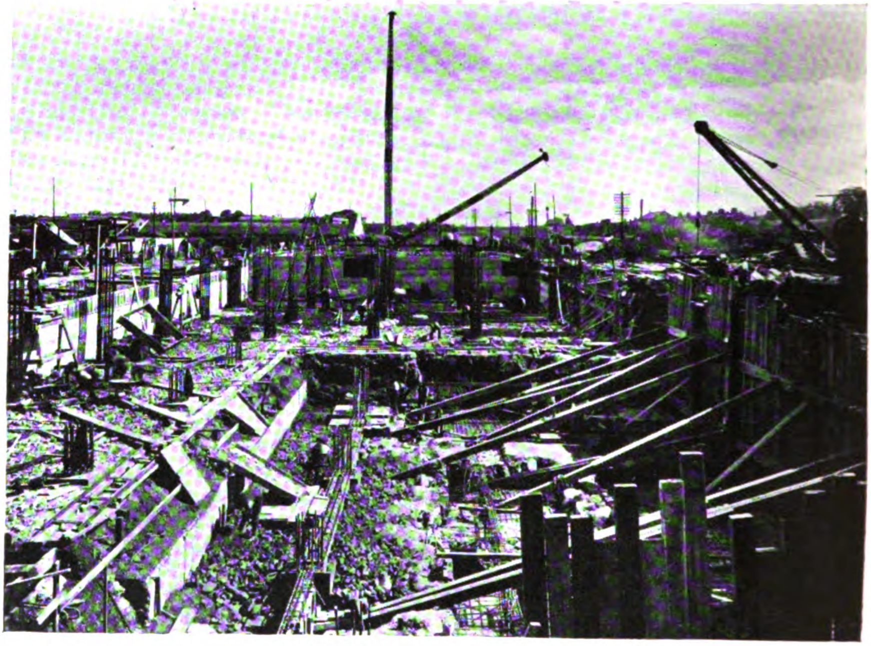
Wherever the use of rapid-hardening Portland cement could expedite the progress it was used. The mushroom floors were struck after six days and an entire story has been completed in fourteen days. The outside dimensions of the building are approximately 227 ft. by 75 ft.

The illustrations on pages 728 and 729 gives an idea of the speed that is being achieved, although great difficulties in excavation and the influence of the general strike made progress slow at the commencement.

The architects are Messrs. Wallis, Gilbert & Partners ; the engineers are The Trussed Concrete Steel Co., Ltd. ; and the contractors Messrs. A. Roberts & Co., Ltd.



Gravel Concrete with Scrubbed Face.



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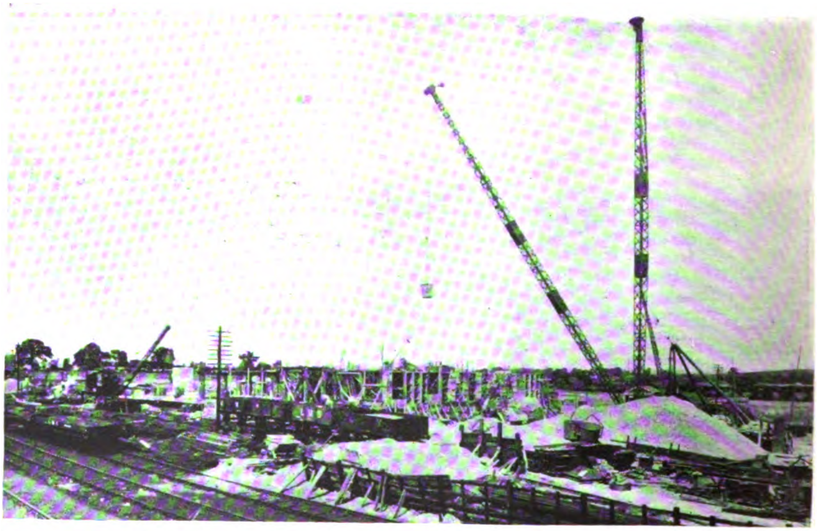

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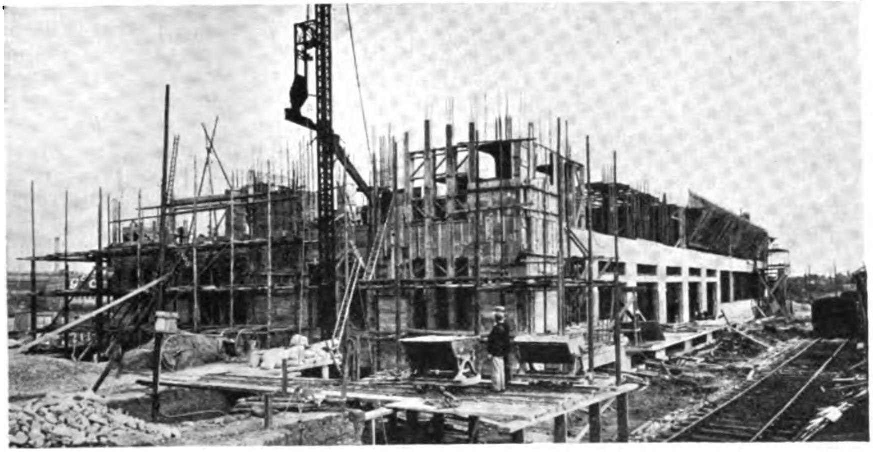
Rapid Concrete Construction. (*See p.* 727.)



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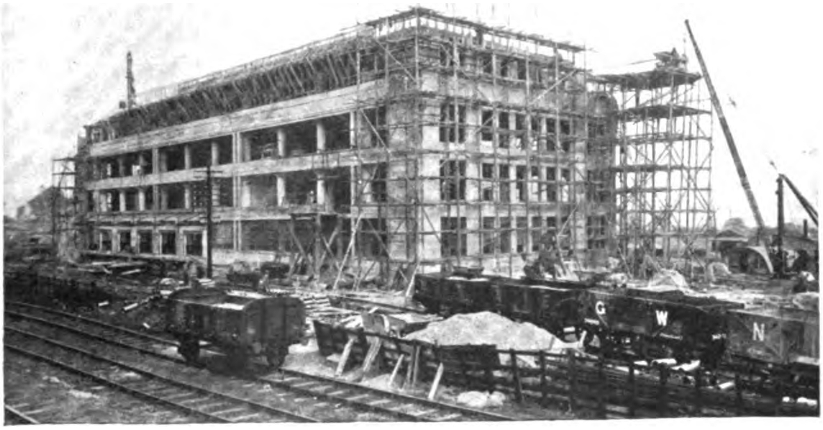


On October 1.

Rapid Concrete Construction. (*See p.* 727.)

Book Reviews.

Building Construction. Part 2. Advanced Course. By Charles F. Mitchell and George A. Mitchell, F.R.I.B.A.

Tenth Edition, 1925. Pp. viii + 999. 7½ × 5 in.
London: B. T. Batsford, Ltd. Price 10/6.

This is the latest edition of a work that is well established as a reference and text book on building construction. A mass of valuable information on all matters pertaining to general building is contained in its twenty-eight chapters. The sources and manufacture of materials are described in considerable detail, together with their uses and properties, and the methods and operations of the successive trades in building procedure are fully illustrated. There are, in addition, chapters on graphic statics, girders, etc., introducing the student to the elements of steelwork and reinforced concrete design.

The chapters dealing with the latter have been rewritten and extended in this issue, one hundred pages being devoted to reinforced concrete alone. These contain the R.I.B.A. and L.C.C. Regulations relative thereto, followed by explanatory notes and worked-out examples. It is to be regretted that the student is taught in these examples to use flat strip for stirrups, an obsolete and undesirable practice. Also, from practical considerations alone it is necessary to have bars at the top of all beams. Apart, however, from these minor points it forms a most comprehensive handbook on the details of general building construction. Mention should also be made of the appendix giving the syllabus of the Lancashire and Cheshire Union of Institutes and recent examination papers of the R.I.B.A., the Surveyors Institution and of the abovementioned Union.—L. T.

Handbuch für Eisenbetonbau—Wasserbau und verwandte Anwendungen. By F. Emperger.

Berlin: W. Ernst & Son. 36 R.M.

This volume, the fourth in the third edition of the well-known German treatise in fourteen volumes on reinforced concrete, deals in the thorough fashion of its predecessors with coast-protection, tide deflectors, wharves, quay-walls, caissons, docks, lighthouses, weirs, dams, and concrete ships. The method of treating these different kinds of engineering works is to give descriptions, with very many excellent illustrations and sketches of details, of the various important structures which have been erected in all parts of the world rather than to compile a theoretical treatise. This particular volume is, in this way, very different from the others, e.g. *Flussigkeitsbehalter* (vol. 5), which contain many mathematical analyses. References, however, are given to treatments of the calculations required in this class of work.

An illustrated list of the standard German symbols for reinforced concrete and strength of materials is a new feature which will be of value to engineers, outside Germany, using the book.

The section devoted to dams, which is nearly one-third of the contents of the volume, treats with hollow dams, which are made possible by reinforced concrete, at length. Important constant-radius and constant-angle dams are described in a manner which is likely to be useful to hydro-electric engineers in the Dominions.

The remarkable curved dams erected in New South Wales, to the design of Mr. Wade, are the subject of a special section. These, as is well-known, were designed by using the " cylinder " formula and are extremely light in cross-section.

Several experiments have been carried out to find (*a*) the internal temperature and (*b*) the deflection of curved dams. The results of these are graphed.

A list of the most important dams of various types will be of interest to many engineers. The indexing is good and the illustrations, as stated above, excellent. The book itself can be highly recommended to engineers with a knowledge of German.—W. S. G.

"Pitman's Building Educator." Edited by Richard Greenhalgh.

London: Sir Isaac Pitman & Sons, Ltd. In 30 fortnightly parts. Price, 1*s.* 3*d.* per part.

A good list of authorities has been got together for the compilation of this work, of which the primary object is to help students and to educate those engaged in one branch of the building industry in the work of the other branches. The subjects, arranged as " lessons," range from architectural design to plumbing and gas fitting. From the first part, now before us, it is impossible to estimate the value of the complete work, as most of the subjects are dealt with in an introductory manner—some of them to the extent of six or seven hundred words only.

Reinforced Concrete Culverts.

A SPECIFICATION for the design and construction of reinforced concrete pipes for culverts has been prepared by a Committee representative of technical and engineering societies, and issued by the American Concrete Institute as a standard specification.

Among the provisions of the specification are the following :—

Design.

The pipe shall be designed in accordance with the following assumptions :

(*a*) The stress per square inch in compression for the concrete shall be four-tenths of its ultimate compressive strength at the age of 28 days, as determined from tests of 6 in. by 12 in. cylinders or 8 in. by 16 in. cylinders.

(*b*) The ratio of the modulus of elasticity of steel to that of concrete shall be 12 for concrete having an ultimate compressive strength at 28 days of 2,200 to 2,900 lbs. per sq. in. and 10 for concrete having an ultimate compressive strength greater than 2,900 lbs. per sq. in.

(*c*) The unit stress for the reinforcement shall not be more than one-half the unit stress at the yield point.

(*d*) The distance from the centre of the reinforcement to the nearest or tension surface of the concrete shall not be less than ¾ in. for pipe 36 in. or less in diameter, or less than 1 in. for pipe more than 36 inches in diameter.

(*e*) The distance from the centre of the tension reinforcement to the compression surface of the concrete and the area of the reinforcement shall not be less than that required by the formula—

$$\frac{wd}{16} \times \frac{d+t}{12} = jAtf_s$$

in which

w = uniform load in lbs. per sq. ft. top and bottom of pipe

d = internal diameter of pipe in inches

t = distance centre of tension reinforcement to compression surface of concrete in inches

A = sectional area of tension reinforcement in square inches per lineal foot of the pipe

f_s = stress in tension in lbs. per sq. in. in the reinforcement

j = ratio of lever arm of reinforcement to "t."

The values of "j" and the percentage of reinforcement shall be determined by the usual formulas.

The uniform load for the Standard Reinforced Concrete Culvert Pipe shall be 2,500 lbs. and for the Extra Strength Reinforced Concrete Culvert Pipe 4,000 lbs. per sq. ft. respectively. The concentrated load shall be considered to be two-fifths of the uniform load.

The shell thickness and the area of the circular reinforcement shall not be less than that given in the following design tables for the classes and sizes of pipe and the strength of concrete therein specified.

Pipe of the internal diameters given in the design tables shall be considered standard sizes for culvert construction. Elliptical pipe shall have the inside horizontal or minor axis equal to the diameter of the corresponding size of circular pipe.

The ends of the pipe shall be of such design that the pipe when laid shall make a continuous and uniform line with a smooth and unbroken interior surface.

When a single line of circular reinforcement is used in circular pipe, it shall be placed near the inner surface of the pipe. When two lines of reinforcement are used in circular pipe, one shall be placed near the inner and one near the outer surface of the pipe. The single line of elliptical reinforcement used in circular pipe, or the single line of circular reinforcement in elliptical pipe shall be placed near the inner surface in the vertical or major axis and near the outer surface in the horizontal or minor axis.

The reinforcement shall be lapped not less than thirty diameters, or, if welded, the joints shall develop the full strength of the reinforcement.

Each line of circular reinforcement shall have sufficient longitudinal bars or members, extending through the barrel of the pipe to afford rigidity and maintain the reinforcement in exact shape and correct position within the form.

The bell shall have circular reinforcement equal in unit area to that of a single line within the barrel of the pipe.

Strength Tests.

Pipe may be tested by either of the following methods :

(*a*) When tested by three-edge bearing

Design Table I

STANDARD REINFORCED CONCRETE CULVERT PIPES.
UNIFORM LOAD 2,500 LBS. PER SQUARE FOOT.
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE 2,750 LBS. PER SQ. IN. AT 28 DAYS.

Internal Diameter Inches "d"	Min. Shell Thickness Inches	Min. Dist. Center Reinf. to Compression Surface "t" Inches	Minimum Area Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
			Cold Drawn Steel Wire $f_s=27,500$		Billet Steel $f_s=20,000$	
			Circular Pipe	Elliptical* Pipe	Circular Pipe	Elliptical* Pipe
12"	1¾	1	1 line 0.08	1 line 0.08	1 line 0.12	1 line 0.12
15"	2	1¼	1 " 0.10	1 " 0.10	1 " 0.15	1 " 0.15
18"	2¼	1½	1 " 0.12	1 " 0.12	1 " 0.19	1 " 0.19
24"	2⅞	2	1 " 0.16	1 " 0.16	1 " 0.23	1 " 0.23
30"	3⅜	2⅝	1 " 0.20	1 " 0.20	1 " 0.30	1 " 0.30
36"	3⅞	3⅛	2 " ea. 0.24	1 " 0.24	2 " ea. 0.36	1 " 0.36
42"	4½	3½	2 " " 0.30	1 " 0.30	2 " " 0.42	1 " 0.42
48"	5	4	2 " " 0.34	1 " 0.34	2 " " 0.48	1 " 0.48
54"	5½	4½	2 " " 0.38	1 " 0.38	2 " " 0.54	1 " 0.54
60"	6	5	2 " " 0.42	1 " 0.42	2 " " 0.60	1 " 0.60
72"	7	6	2 " " 0.50	1 " 0.50	2 " " 0.71	1 " 0.71
84"	8	7	2 " " 0.58	1 " 0.58	2 " " 0.83	1 " 0.83

*The number of lines and area of elliptical reinforcement in circular pipe shall be the same as the number of the lines and area of the circular reinforcement in elliptical pipe.

Design Table II

UNIFORM LOAD 2,500 LBS. PER SQUARE FOOT.
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE 4,000 LBS. PER SQ. IN. AT 28 DAYS.

Internal Diameter Inches "d"	Min. Shell Thickness Inches	Min. Dist. Center Reinf. to Compression Surface "t" Inches	Minimum Area Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
			Cold Drawn Steel Wire $f_s=27,500$		Billet Steel $f_s=20,000$	
			Circular Pipe	Elliptical* Pipe	Circular Pipe	Elliptical* Pipe
12"	1½	¾	1 line 0.10	1 line 0.10	1 line 0.17	1 line 0.17
15"	1¾	1	1 " 0.13	1 " 0.13	1 " 0.19	1 " 0.19
18"	2	1¼	1 " 0.16	1 " 0.16	1 " 0.22	1 " 0.22
24"	2⅜	1⅝	1 " 0.21	1 " 0.21	1 " 0.30	1 " 0.30
30"	2¾	2	1 " 0.26	1 " 0.26	1 " 0.38	1 " 0.38
36"	3⅛	2⅜	2 " ea. 0.31	1 " 0.31	2 " ea. 0.45	1 " 0.45
42"	3¾	2¾	2 " " 0.37	1 " 0.37	2 " " 0.54	1 " 0.54
48"	4⅛	3⅛	2 " " 0.42	1 " 0.42	2 " " 0.61	1 " 0.61
54"	4⅝	3⅝	2 " " 0.47	1 " 0.47	2 " " 0.67	1 " 0.67
60"	5	4	2 " " 0.52	1 " 0.52	2 " " 0.75	1 " 0.75
72"	5¾	4¾	2 " " 0.63	1 " 0.63	2 " " 0.90	1 " 0.90
84"	6½	5½	2 " " 0.73	1 " 0.73	2 " " 0.99	1 " 0.99

*The number of lines and area of elliptical reinforcement in circular pipe shall be the same as the number of the lines and area of the circular reinforcement in elliptical pipe.

Design Table III

EXTRA STRENGTH REINFORCED CONCRETE CULVERT PIPE.
UNIFORM LOAD 4,000 LBS. PER SQUARE FOOT.
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE 2,750 LBS. PER SQ. IN. AT 28 DAYS.

Internal Diameter Inches "d"	Min. Shell Thickness Inches	Min. Dist. Center Reinf. to Compression Surface "t" Inches	Minimum Area Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
			Cold Drawn Steel Wire $f_s=27,500$		Billet Steel $f_s=20,000$	
			Circular Pipe	Elliptical* Pipe	Circular Pipe	Elliptical* Pipe
12"	2⅛	1⅜	1 line 0.11	1 line 0.11	1 line 0.14	1 line 0.14
15"	2⅜	1⅝	1 " 0.13	1 " 0.13	1 " 0.19	1 " 0.19
18"	2¾	2	1 " 0.15	1 " 0.15	1 " 0.22	1 " 0.22
24"	3⅜	2⅝	1 " 0.21	1 " 0.21	1 " 0.29	1 " 0.29
30"	4	3¼	1 " 0.26	1 " 0.26	1 " 0.38	1 " 0.38
36"	4¾	4	2 " ea. 0.31	1 " 0.31	2 " ea. 0.43	1 " 0.43
42"	5⅜	4⅝	2 " " 0.36	1 " 0.36	2 " " 0.52	1 " 0.52
48"	6¼	5¼	2 " " 0.41	1 " 0.41	2 " " 0.60	1 " 0.60
54"	7	6	2 " " 0.46	1 " 0.46	2 " " 0.66	1 " 0.66
60"	7⅝	6⅝	2 " " 0.52	1 " 0.52	2 " " 0.72	1 " 0.72
72"	9	8	2 " " 0.62	1 " 0.62	2 " " 0.86	1 " 0.86
84"	10¼	9¼	2 " " 0.72	1 " 0.72	2 " " 1.02	1 " 1.02

*The number of lines and area of elliptical reinforcement in circular pipe shall be the same as the number of the lines and area of the circular reinforcement in elliptical pipe.

Design Table IV

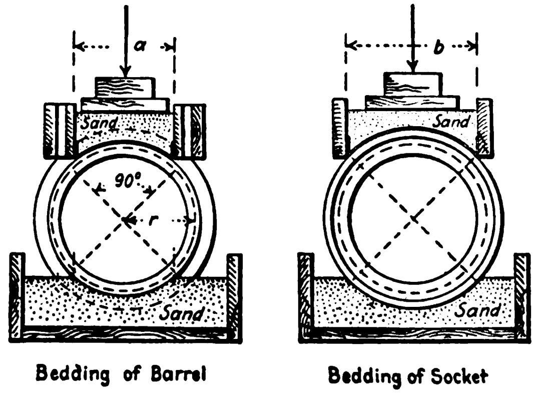
UNIFORM LOAD 4,000 LBS. PER SQUARE FOOT.
ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE 4,000 LBS. PER SQ. IN. AT 28 DAYS.

Internal Diameter Inches "d"	Min. Shell Thickness Inches	Min. Dist. Center Reinf. to Compression Surface "t" Inches	Minimum Area Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
			Cold Drawn Steel Wire $f_s=27,500$		Billet Steel $f_s=20,000$	
			Circular Pipe	Elliptical* Pipe	Circular Pipe	Elliptical* Pipe
12"	1¾	1	1 line 0.13	1 line 0.13	1 line 0.20	1 line 0.20
15"	2	1¼	1 " 0.17	1 " 0.17	1 " 0.25	1 " 0.25
18"	2¼	1½	1 " 0.20	1 " 0.20	1 " 0.30	1 " 0.30
24"	2⅞	2	1 " 0.26	1 " 0.26	1 " 0.39	1 " 0.39
30"	3⅜	2⅝	1 " 0.33	1 " 0.33	1 " 0.49	1 " 0.49
36"	3⅞	3⅛	2 " ea. 0.40	1 " 0.40	2 " ea 0.58	1 " 0.58
42"	4½	3½	2 " " 0.46	1 " 0.46	2 " " 0.68	1 " 0.68
48"	5	4	2 " " 0.53	1 " 0.53	2 " " 0.78	1 " 0.78
54"	5½	4½	2 " " 0.59	1 " 0.59	2 " " 0.88	1 " 0.88
60"	6	5	2 " " 0.66	1 " 0.66	2 " " 0.96	1 " 0.96
72"	7	6	2 " " 0.79	1 " 0.79	2 " " 1.16	1 " 1.16
84"	8	7	2 " " 0.92	1 " 0.92	2 " " 1.36	1 " 1.36

*The number of lines and area of elliptical reinforcement in circular pipe shall be the same as the number of the lines and area of the circular reinforcement in elliptical pipe a machine shall be used which gives a uniform deflection throughout the full length of the pipe. The lower bearing for the pipe shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ in. The strips shall be straight and shall be securely fastened to a rigid block with the interior vertical sides spaced a distance apart not less than ½ in. or more than 1 in. for each foot of diameter of pipe. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of pipe exclusive of bell. The pipe shall be placed symmetrically between the two bearings as illustrated in *Figs*. 3 and 4.

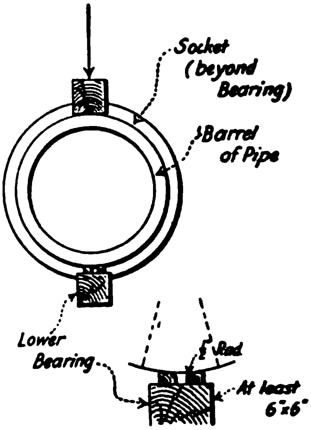
(*b*) When sand bearings are used (see *Figs*. 2 and 5), the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel. The sand used shall be clean and dry and shall be such as will pass a No. 4 screen.

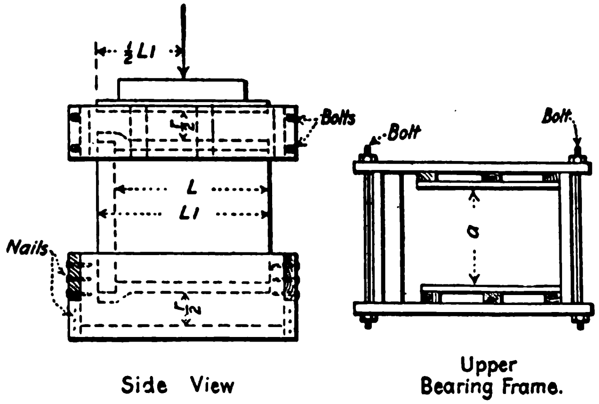
The top bearing frame shall not be allowed to come in contact with the pipe or with the top bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight-edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be



Bedding of Barrel

Bedding of Socket





Side View

Upper Bearing Frame.

Fig. 2
Sand Bearings

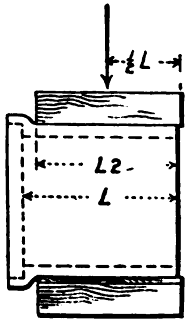
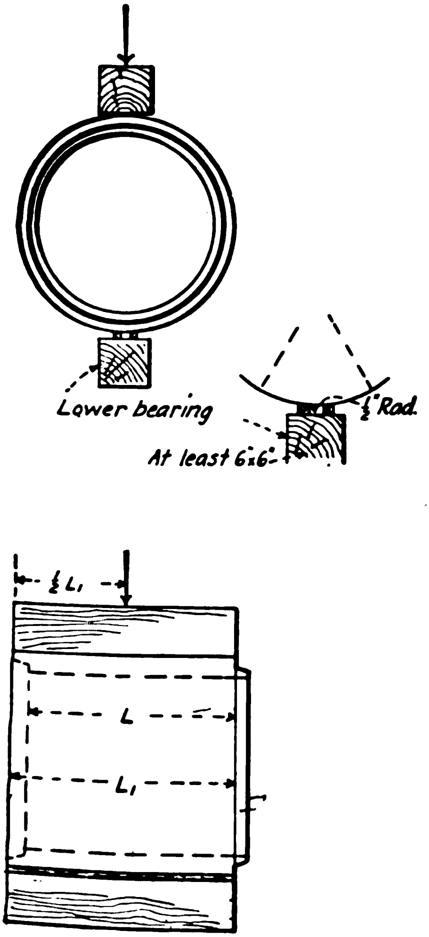


Fig. 3
Three Edge Bearings

applied at the exact centre of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the centre of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

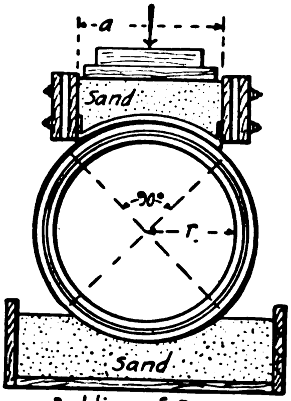
The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

(*c*) Any prime mover or hand power which will apply the load at a uniform rate of about 2,000 lbs. per minute, or in increments of not more than 100 lbs.,

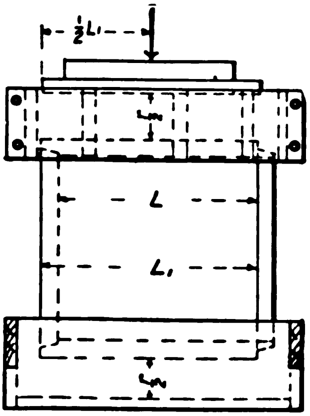


Side View

Fig. 4
Three Edge Bearings



Bedding of Barrel



Side View

Fig. 5
Sand Bearings

at the same rate, may be used in making the test. The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The load shall be applied continuously until the ultimate strength of the pipe is reached. The load at ultimate strength and also when the first crack appears shall be observed and recorded.

In testing pipe which is " out of line " the lines of the bearings chosen shall be from those which appear to give the most favourable conditions for fair test.

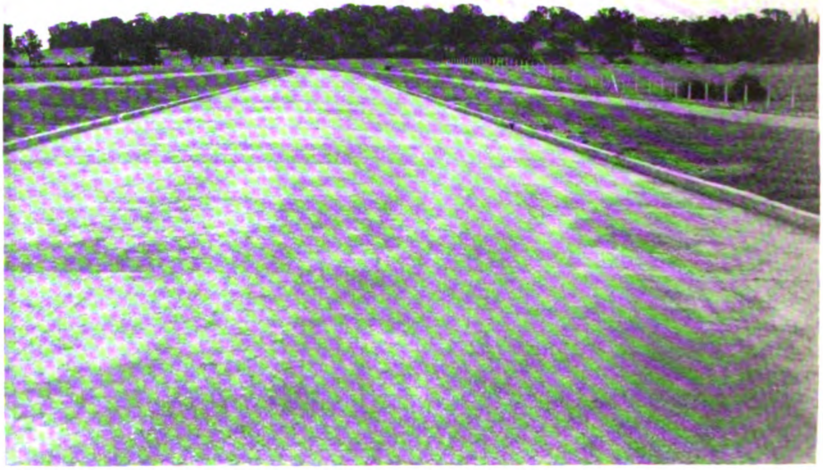
When tested by either method the pipe shall meet the following requirements :

Standard Reinforced Concrete Culvert Pipe.—The ultimate load in pounds per lineal foot by the three-edge bearing test shall be not less than 2,000 times the nominal internal diameter of the pipe in feet. When loaded to one-half the minimum ultimate load, there shall be no crack in the barrel of the pipe having a surface width of 1/100 in. or more for a length of 2 ft. or more. The ultimate load is reached when the pipe will sustain no additional load.

Extra Strength Reinforced Concrete Culvert Pipe.—The ultimate load in pounds per lineal foot by the three-edge bearing test shall be not less than 3,200 times the nominal internal diameter of the pipe in feet. When loaded to one-half the minimum ultimate load, there shall be no crack in the barrel of the pipe having a surface width of 1/100 in. or more for a length of 1 ft. or more. The ultimate load is reached when the pipe will sustain no additional load.

When pipes are tested by the sand bearing method the minimum ultimate loads and cracking loads shall be 1½ times those specified for three-edge bearing.

Elliptical pipe shall meet the test requirements for circular pipe having the same horizontal internal diameter.



Watford By-Pass Road.

[This is an all-concrete road, 8 in. thick, reinforced with B.R.C. fabric. Lt.-Col. A. E. Prescot, D.S.O., is the County Surveyor for Hertfordshire. The contractors were Sir Robert McAlpine & Sons.]

Table of Dimensions for Solid Reinforced Concrete Slabs.

By J. F. HURTER.

THE purpose of the present table (see pp. 738–739) is to reduce to a minimum the work of calculation for solid reinforced concrete slabs, as particularly the preparation of estimates for public tenders entails a considerable amount of non-productive work involving considerable expenditure of time. Further, the table should be useful to the architect in preparing designs, as it gives rapid information as to the thickness of floor slabs.

It is true that tables of dimensions are to be found in various text-books, and some of the leading firms have worked out their own data in some form or other. The time spent on these calculations, however, is still too great, as the moments have always to be calculated first, so that with the aid of the tables the thickness of the slab and the suitable round steel section may be found.

In practice the spans and requisite effective loads are always to be found at once in the plans. In preparing estimates the extent of the moment resulting from width of span and effective load is scarcely of interest ; on the other hand, the main point is to ascertain quantities as quickly as possible in order to insert prices in the estimates.

The present table is based on the two known quantities, i.e. widths of span and effective loads. From this table we obtain the thickness of slabs and the corresponding round steel sections directly, avoiding the calculation of moments.

The basic formula employed, which we assume as well known, is

$$d = \frac{t + c.m}{c} \cdot \sqrt{\frac{6.B}{m.b.(3t + 2.c.m)}}$$

The calculations are based on the Reinforced Concrete Regulations of the London County Council (General Powers) Act, 1909. Inserting the values c, t, m in accordance with these Regulations and assuming the width of slab as $b = 12$ in., we obtain for the above formula, resolved according to B

$$B = d^2 \times 1149{,}48 \text{ lb. ins.}$$

Therefore with any value of d (i.e. with any effective thickness of slab) we find that in accordance with these Regulations there can only be *one maximum moment B*. The extent of this moment with any width of span or effective load will always give a certain fixed effective load or width of span respectively, whilst the permissible stresses in concrete and steel are not exceeded.

Therefore the width of span varies in proportion to the effective load. In the small table at the bottom right-hand corner are given these maximum moments for the thickness of slabs h (3–10 in.). From this point we proceed to determine the widths of span, increasing effective loads by 10 lbs. per sq. ft. for the above-mentioned slab thicknesses. Thus :

$$B = \tfrac{1}{8} l^2 . W \text{ to } \tfrac{1}{24} l.^2 W$$

according to the extent to which the slab is fixed.

Now if we plot a co-ordinate system of axes, and draw the effective loads as abscissæ, the widths of span as ordinates, we obtain the maximum curve for

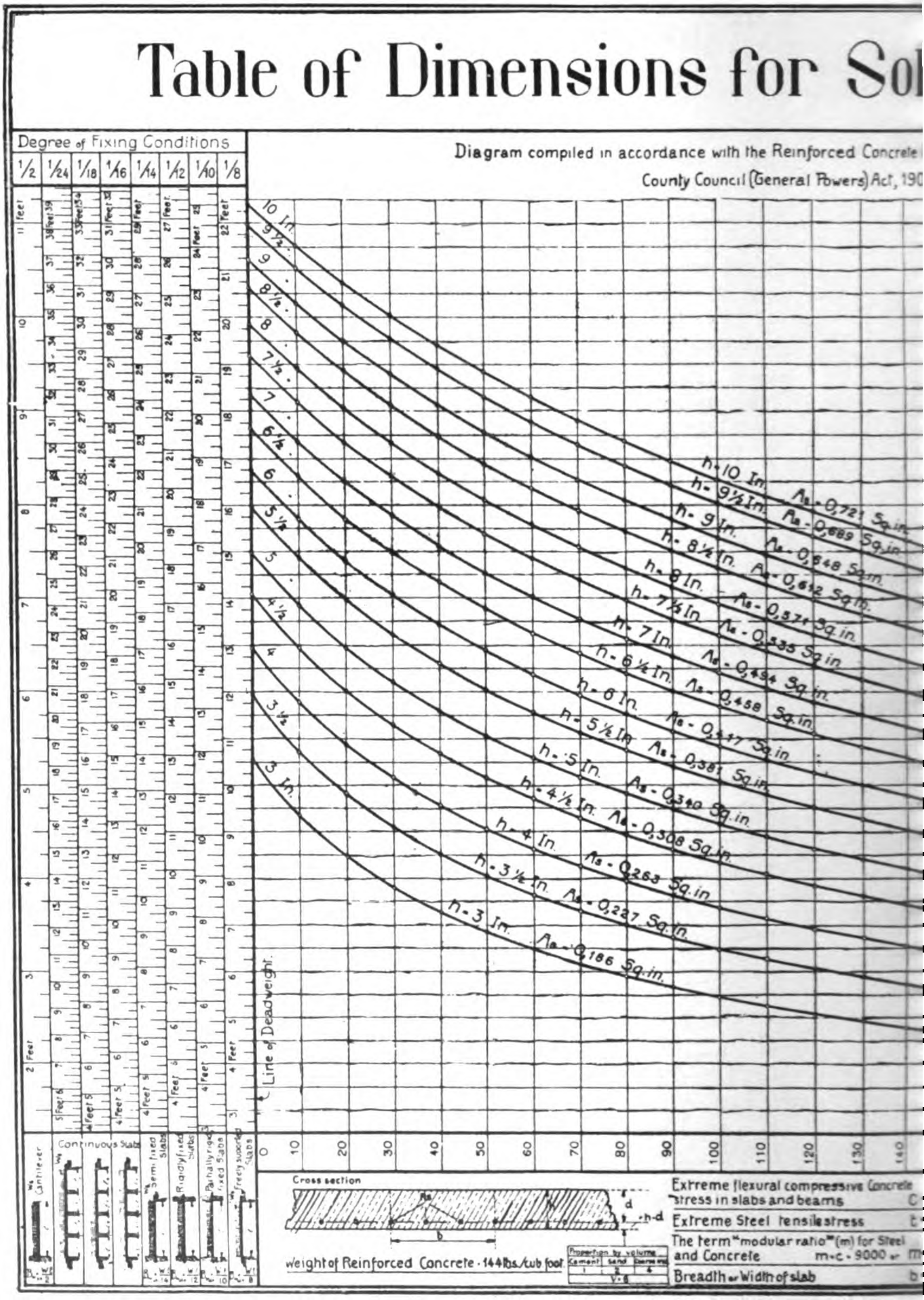


Table of Dimensions for So
Degree of Fixing Conditions
1/2
1/24
1/18
1/16
1/14
1/12
1/10
1/8
Diagram compiled in accordance with the Reinforced Concrete
County Council (General Powers) Act, 190
11 Feet
2 Feet
Line of Deadweight
10 In.
9 1/2
9
8 1/2
8
7 1/2
7
6 1/2
6
5 1/2
5
4 1/2
4
3 1/2
3 In.
h-10 In. As-0,721 Sq.in
h-9 1/2 In. As-0,689 Sq.in
h-9 In. As-0,648 Sq.in
h-8 1/2 In. As-0,612 Sq.in
h-8 In. As-0,571 Sq.in
h-7 1/2 In. As-0,535 Sq.in
h-7 In. As-0,494 Sq.in
h-6 1/2 In. As-0,458 Sq.in
h-6 In. As-0,417 Sq.in
h-5 1/2 In. As-0,381 Sq.in
h-5 In. As-0,340 Sq.in
h-4 1/2 In. As-0,308 Sq.in
h-4 In. As-0,263 Sq.in
h-3 1/2 In. As-0,227 Sq.in
h-3 In. As-0,186 Sq.in
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Cantilever
Continuous Slabs
Semi fixed Slabs
Rigidly fixed Slabs
Partially rigid fixed Slabs
Freely supported Slabs
Cross section
As
d
h-d
b
Weight of Reinforced Concrete 144 lbs./cub foot.
Proportion by volume
Cement 1 Sand 2 Stones 4
Extreme flexural compressive Concrete stress in slabs and beams
Extreme Steel tensile stress
The term "modular ratio" (m) for Steel and Concrete m-c-9000
Breadth or Width of slab b

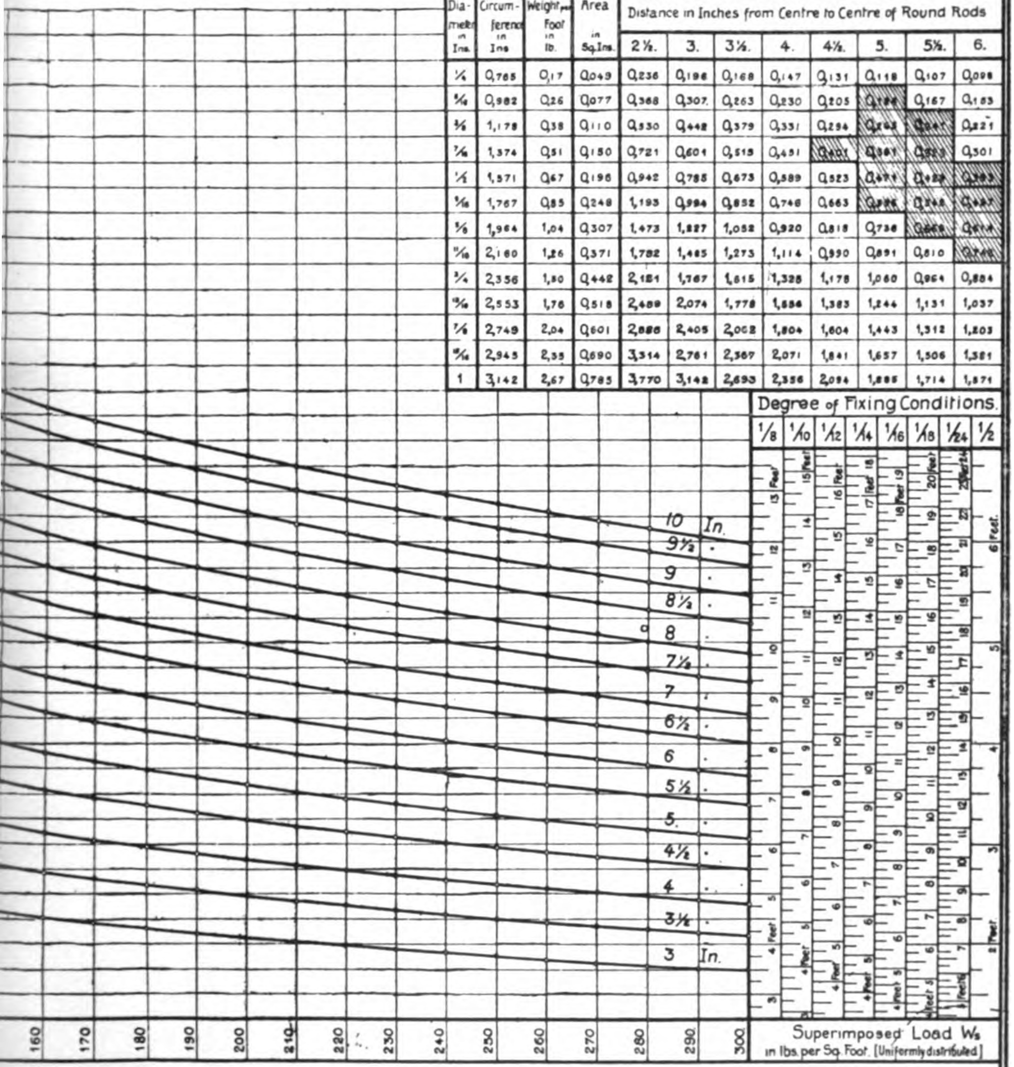
(See

d Reinforced Concrete Slabs.

gulations of the London

Table giving the Sectional Areas of Round Rods at various Distances apart, in 1 Foot Width of Slab.~

Diameter in Ins.	Circumference in Ins	Weight per Foot in lb.	Area in Sq. Ins.	Distance in Inches from Centre to Centre of Round Rods							
				2½.	3.	3½.	4.	4½.	5.	5½.	6.
¼	0,785	0,17	0,049	0,236	0,196	0,168	0,147	0,131	0,118	0,107	0,098
5/16	0,982	0,26	0,077	0,368	0,307	0,263	0,230	0,205	0,184	0,167	0,153
⅜	1,178	0,38	0,110	0,530	0,442	0,379	0,331	0,294	0,265	0,241	0,221
7/16	1,374	0,51	0,150	0,721	0,601	0,515	0,451	0,401	0,361	0,328	0,301
½	1,571	0,67	0,196	0,942	0,785	0,673	0,589	0,523	0,471	0,428	0,393
9/16	1,767	0,85	0,248	1,193	0,994	0,852	0,746	0,663	0,596	0,542	0,497
⅝	1,964	1,04	0,307	1,473	1,227	1,052	0,920	0,818	0,736	0,669	0,614
11/16	2,160	1,26	0,371	1,782	1,485	1,273	1,114	0,990	0,891	0,810	0,742
¾	2,356	1,50	0,442	2,121	1,767	1,515	1,328	1,178	1,060	0,964	0,884
13/16	2,553	1,76	0,518	2,489	2,074	1,778	1,556	1,383	1,244	1,131	1,037
⅞	2,749	2,04	0,601	2,886	2,405	2,062	1,804	1,604	1,443	1,312	1,203
15/16	2,945	2,35	0,690	3,314	2,761	2,367	2,071	1,841	1,657	1,506	1,381
1	3,142	2,67	0,785	3,770	3,142	2,693	2,356	2,094	1,885	1,714	1,571



-50V - 600 lbs/in²
00 lbs/in²
- 15
in.

Thickness h in.	Effect. Depth d in.	h-d in.	Bending Moment lbs. in.	Area of Steel Sq. in.	Weight lbs/Sq.ft.	Thickness h in.	Effect. Depth d in.	h-d in.	Bending Moment lbs. in.	Area of Steel Sq. in.	Weight lbs/Sq.ft.	Thickness h in.	Effect. Depth d in.	h-d in.	Bending Moment lbs. in.	Area of Steel Sq. in.	Weight lbs/Sq.ft.
3	2,30	0,70	6033	0,1863	36	5½	4,70	0,80	25193	0,3807	66	8	7,05	0,95	56684	0,5710*	96
3½	2,80	0,70	8941	0,2268	42	6	5,15	0,85	30248	0,4171*	72	8½	7,55	0,95	65010	0,6115*	102
4	3,25	0,75	12046	0,2632*	48	6½	5,65	0,85	36406	0,4576*	78	9	8,00	1,00	72989	0,6480	108
4½	3,75	0,75	16037	0,3037*	54	7	6,10	0,90	42436	0,4941	84	9½	8,50	1,00	82400	0,6885	114
5	4,20	0,80	20118	0,3402	60	7½	6,60	0,90	49677	0,5346	90	10	8,90	1,10	90335	0,7209	120

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each thickness of slab. These curves give the effective load corresponding to each width of span, and vice versa.

As, however, a maximum steel section is required for each maximum moment, we could also embody in a simple manner in each curve ; that is to say, for each thickness of slab the corresponding steel section, calculated for a slab of 12 in. width (*b*).

The table of round steel in the top right-hand corner enables us to find at a glance the diameter and spacing of two round steel bars for each of the requisite steel sections shown in the curve. It should be borne in mind that the hatched portions represent the most advisable distribution of reinforcement over the section.

We would refer to the formula :

$$A_s = \frac{m \, . \, b \, . \, d \, . \, c^2}{2 \, . \, t \, . \, (t + m \, . \, c)}$$

Inserting the values m, c, t and the width of slab mentioned above, we get

$$A_s = d \, . \, 0{\cdot}081 \text{ sq. inch.}$$

The ordinate at no load gives the widths of span for dead weight only of the slab, and on this the effective loads from 0 to 300 lbs. per sq. ft. were planned, the dead weight being, of course, included in each case.

For the practical employment of the table, on each side are given scales for various degrees of fixing according to whether the slab is supported at both ends, fixed or semi-fixed, fixed over one or more openings, or in the form of a cantilever or reservoir wall. The object is to provide easy means of recognition of these various cases in a systematic manner.

Thus from this table, by skilful interpolation, we may find the required quantities for the various cases. If the point of intersection of the ordinates and abscissæ for effective load and width of span lies outside the diagram it is most probable that a solid slab would not be practicable for reasons of economy. The slab would then have to be constructed as a floor with beams underneath.

Further, in the small table in the right-hand bottom corner are given all the required values to show that in assuming the effective thickness of slab d we have taken account of practical conditions by providing various proportions of h to d.

The following examples demonstrate the extremely rapid use of the table :

Example No. 1.—A slab supported at both ends has a span $l = 12$ ft., and an effective load $W_s = 90$ lbs. per sq. ft. is to be provided for. We have to find the thickness of slab h and steel section A_s.

From the point of intersection of the ordinate for 12 ft. with $\frac{1}{8}$ fixing with the abscissa for 90 lbs. per sq. ft. we get :

$$h = 6\tfrac{1}{2} \text{ in.}, \ A_s = 0{\cdot}458 \text{ sq. in., or } \tfrac{1}{2}\text{-in. bars at 5-in. centres.}$$

In checking these figures we find from the usual formulæ after calculating $n = 2{\cdot}0952$; then :

$$c = 583 \text{ lbs. per sq. in. ; } t = 14{,}835 \text{ lbs. per sq. in.}$$

Example No. 2.—A fixed slab has a span $l = 14$ ft., and an effective distributed load $W_s = 230$ lbs. per sq. ft. is to be provided for. Find the thickness of slab h and the section A_s.

The point of intersection of the ordinate for 14 ft. with 1/12 fixing with the abscissa for 230 lbs. per sq. ft. shows that :

$$h = 9\tfrac{1}{2} \text{ in.} ; \quad A_s = 0{\cdot}689 \text{ sq. in.}$$

and verifying the stresses :

$$t = 13{,}083 \text{ lbs. per sq. in.} ; \quad c = 491 \text{ lbs. per sq. in.}$$

Example No. 3.—A loading ramp has a cantilever of 5 ft., and the specified effective distributed load is 280 lbs. per sq. ft.

According to the table we find in the dangerous section :

$$h = 8 \text{ in.} ; \quad A_s = 0{\cdot}571 \text{ sq. in.}$$

These figures give the following stresses :

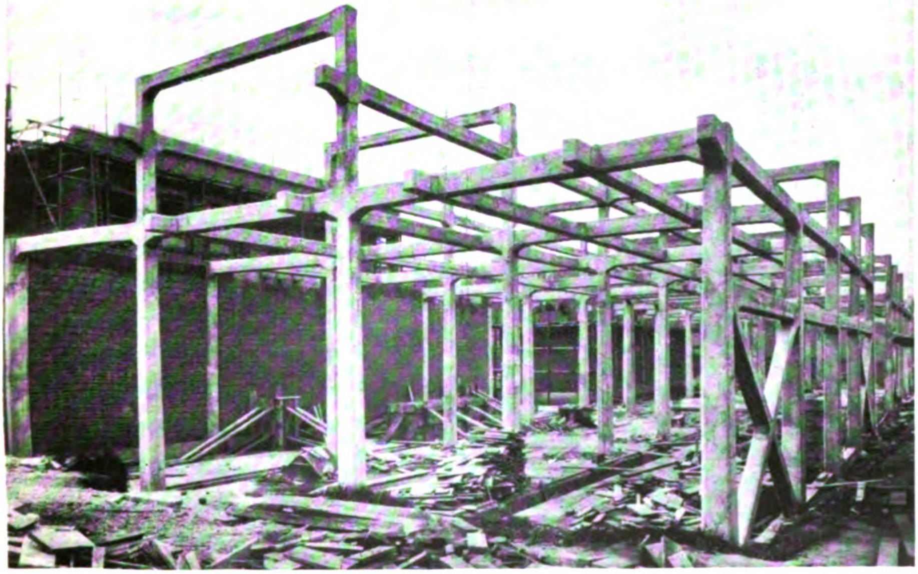
$$t = 15{,}923 \text{ lbs. per sq. in.} ; \quad c = 597 \text{ lbs. per sq. in.}$$

Halesowen Substation.

THE reinforced concrete structure illustrated below was designed by Mr. A. Alban H. Scott, F.R.I.B.A., of 13, Old Square, Lincoln's Inn, W.C.2, for the Shropshire, Worcestershire & Staffordshire Electric Power Co. to the instructions of Mr. C. W. G. Little, Engineer to the Company. Reinforced concrete was used in preference to structural steel so that the substation need not be closed down for painting or other maintenance work.

The concrete is composed of granite chippings, sand and rapid-hardening Portland cement in a 10 : 5 : 3 mixture, and is reinforced with round mild steel rods.

The projecting pieces shown in the photograph are for connecting up in the event of extension of the structure for future plant. The general contractors were Messrs. Maddocks & Walford, of Birmingham.



Substation at Halesowen under Construction.

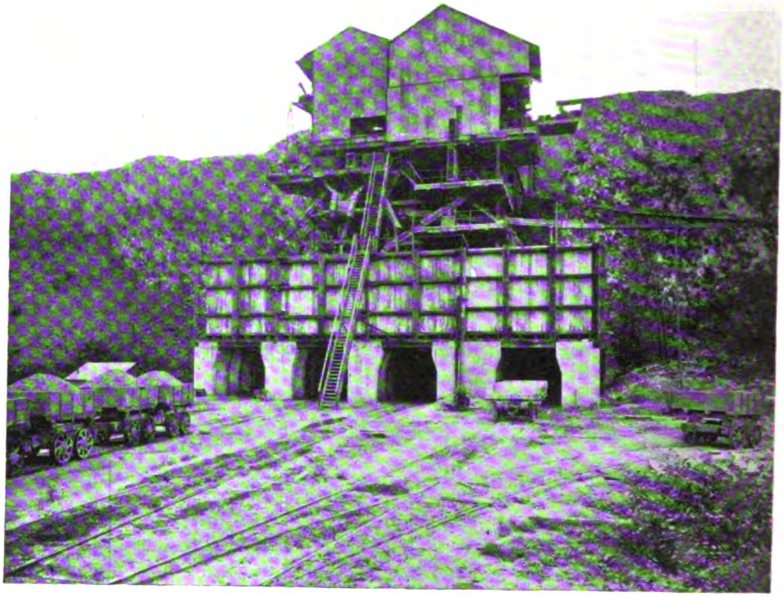


Fig. 1. Front View.

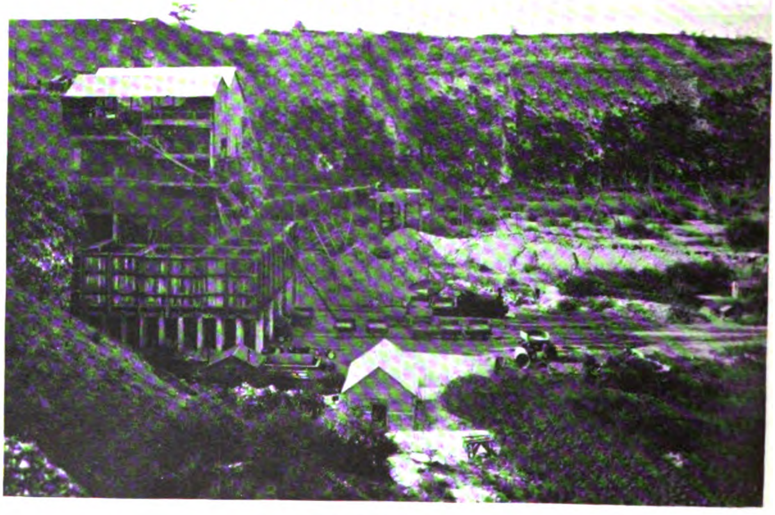


Fig. 2. Side View.

General View of the Plant. (*See p.* 743.)

An Up-to-Date Aggregate Plant.

A REALISATION on the part of architects, engineers, and contractors that good concrete can only be obtained by the use of clean and well-graded aggregates has led to a corresponding effort on the part of suppliers to meet the demand. The time has gone when any sort of gravel and sand, often unwashed, was considered suitable for concrete making. Now only the best materials are asked for, and with the growth of the concrete industry they are required to an extent which makes haphazard methods of excavation and washing and grading an uneconomic proposition. The methods and plant employed on a modern aggregate plant are a revelation to those making their first visit to a large works.

One of the largest suppliers of concrete aggregates in the country is the Stone Court Chalk, Land & Pier Co., Ltd., whose recent extensions have brought the output up to about 6,000 tons a week. Situated near Greenhithe, Kent, the works has access to the river from its own pier, and is connected by its own sidings to the Southern Railway. As will be seen from the photographs, the site is ideal for the purpose. The plant is erected against the cliff in an old excavation and the materials are now excavated from new pits at the higher level. There is thus no need to elevate the materials to the top of the plant.

One of the working faces is shown in *Fig.* 3. As will be seen, the materials are won by hand, without the use of a steam excavator. This is partly because owing to the formation hand labour is found to be cheaper and partly because with hand-labour it is easy to reject any large pieces of clay before they reach the plant and thus prevent any possibility of the washers becoming clogged.

At the face shown in the illustration there are twelve "runs" on which jubilee wagons are filled. When filled they are pushed along the tracks to a single track on which they all converge, where they are linked up into trains of eight or a dozen wagons and taken to the plant by a Fordson tractor.

A train of these wagons on arrival at the plant is shown in *Fig.* 4, which shows

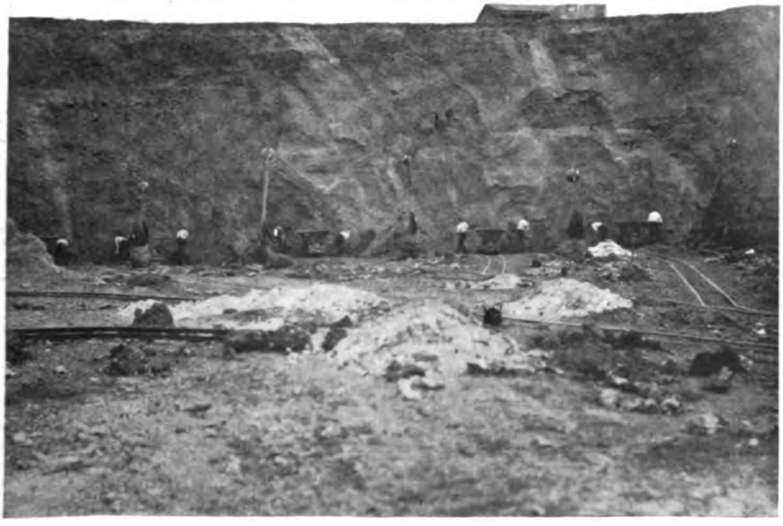


Fig. 3.—One of the Quarry Faces.

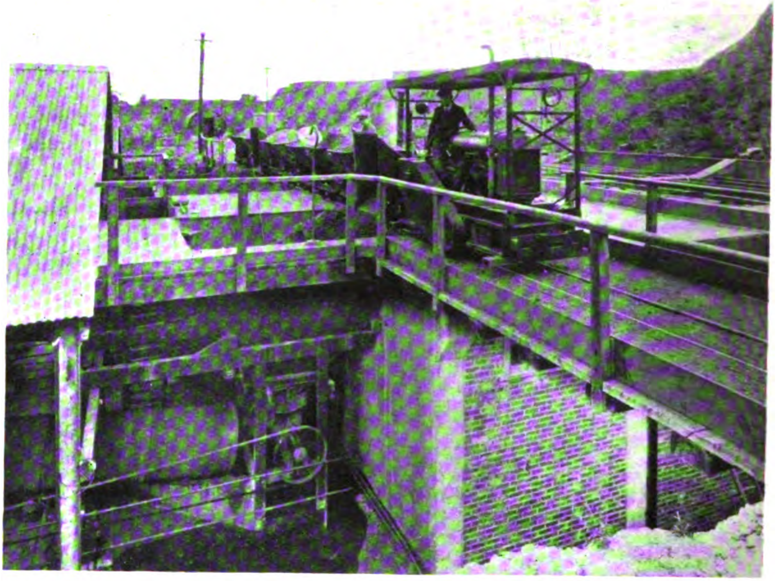


Fig. 4.—Tipping Material into Hopper at Top of Plant.

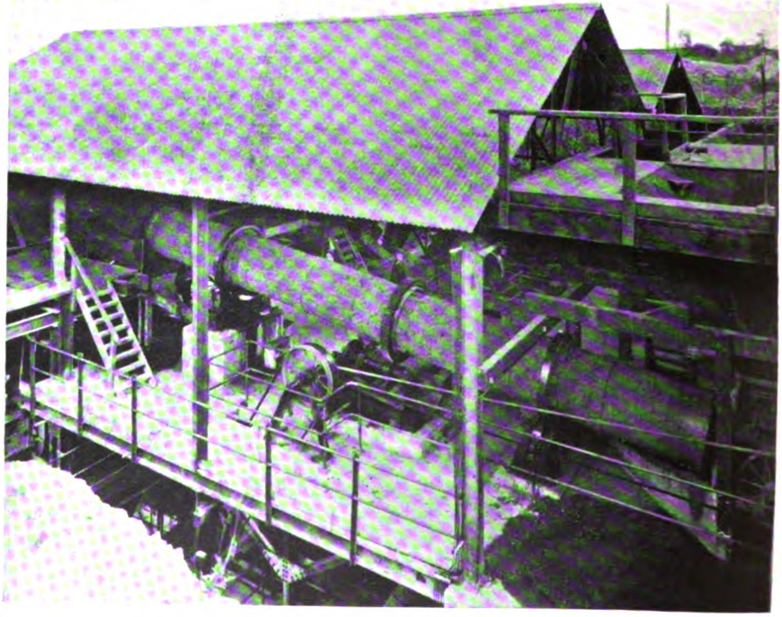


Fig. 5.—One of the Rotary Washers.

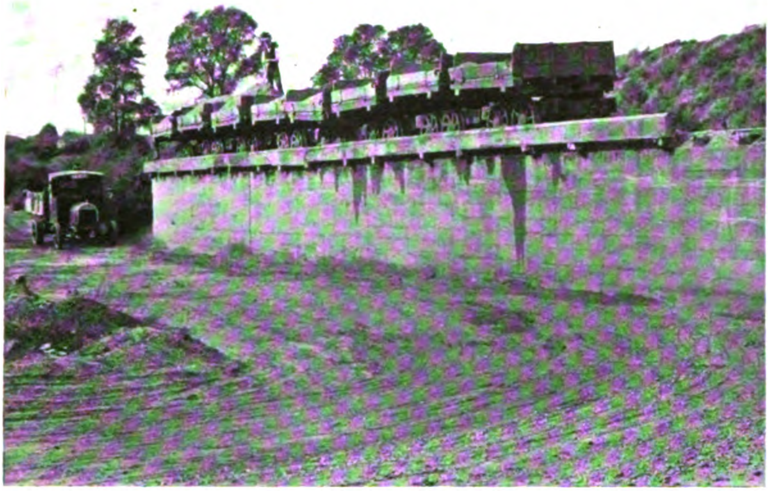


Fig. 6.—Road Loading Dock.

the hoppers into which the material is tipped. These hoppers serve three washers, one of which is shown in *Fig.* 5. The washers are steel cylinders (in this case adapted from rotary cement coolers) up which the material is conveyed by a spiral (from right to left in the photograph). As the material passes slowly up the cylinder, continually turned by the spiral and also by agitators, water is constantly flowing in the reverse direction, so that when the aggregate reaches the end of the washer all clay, loam, fine sand, etc., have been washed away and have passed out at the bottom of the washer from whence they run along the troughs seen in *Fig.* 2 to a settling tank.

As a further precaution against any fine material finding its way into the grading machines the top end of the washer is perforated, and as the washed material is thrown against this perforated plate it is played on by three jets of water which effectively dispose of any sand finer than the perforations. This sand is also conducted by troughs to the settling tank, where the sand is separated from the other materials and recovered.

The washers are at the top of the plant, and each has a capacity of 14 cu. yds. per hour. On the floor below are the crushers, both "Patent Lightning" crushers and Hadfield jaw crushers being installed, together with granulators.

From the crushers and granulators, which reduce the material to a maximum of 1 in., 1½ in., or 2 in., according to requirements, it is conducted to the graders, of which there are three. The graders are of the cylindrical revolving type, with plates perforated with holes of a size according to the grading of the material required. These plates are interchangeable, so that by simple adjustments any desired size may be obtained. Usually plates with perforations of three different sizes are used on each machine, so that as the material passes through the cylinder three sizes pass through different sections, each of which is over its appropriate chute for conveyance to the storage hoppers below. In the grading machines the material is again thoroughly washed, so that when it reaches the storage hoppers it has been washed three times with running water, and on each occasion it has been constantly agitated whilst the water is running through it. The result is an aggregate as clean as it is possible to get it.

Above the loading area are twelve storage bins for different size materials, ranging from sand passing a $\frac{5}{32}$-in. ring to 1$\frac{1}{2}$ in. gravel. The standard products of the company are sand passing $\frac{5}{32}$ in. and $\frac{3}{16}$ in. sieves; $\frac{3}{16}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in. and 1$\frac{1}{2}$ in. gravel; and gravel graded $\frac{3}{4}$ in. to $\frac{3}{8}$ in. and $\frac{3}{4}$ in. to $\frac{5}{32}$ in.; any other size or grading is, of course, supplied to order. One of the special products of the plant is a particularly sharp sand. This is obtained by mixing fine sand with the fine stone from the crushers; these materials are conveyed from the washers and crushers respectively and conveyed to a small hopper, from whence they are picked up by a spiral conveyor which thoroughly mixes the two together on their way to the storage bins.

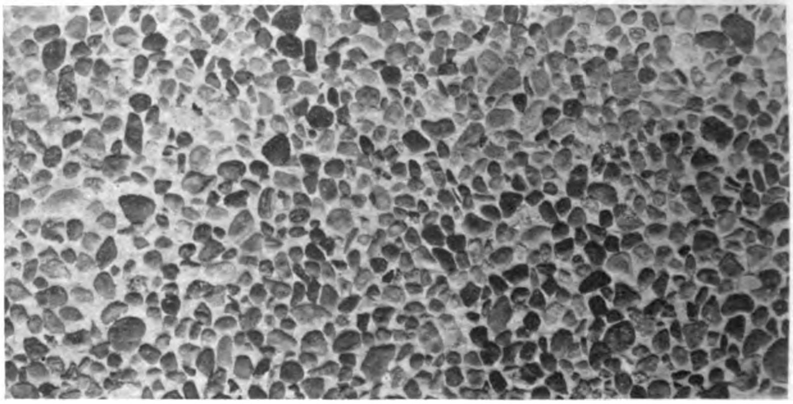
Particular attention has been given to the design of the plant to secure economical working, with the result that from the time the material is tipped into the hoppers at the top until it is discharged into railway trucks at ground level it is conveyed by gravity from one process to another. The plant is also noticeable for its cleanliness; although some 30,000 gallons of water are used per hour the chutes and troughs are so well constructed that none of it finds its way to the floors, and the crushers are well guarded to prevent stones flying out.

Power for the most modern part of the plant is supplied by two Ruston oil engines of 90 and 70 h.p. respectively, which, we are informed, have been in continuous use for three years without giving any trouble whatever, while another Ruston engine has been running for ten years without trouble. These engines, generators, and other plant equipment are installed in a power house built into the chalk at the top of the plant in order to prevent the vibration from the crushers affecting them.

The whole of the plant is well lighted by electricity, as also are the working faces and the track from the pits to the plant. Such is the demand for materials at the present time that for some months the plant has been running 24 hours a day, so that adequate lighting is essential.

The plant is carried on a massive concrete substructure of columns and beams, beneath which run full-gauge railway tracks so that materials may be loaded from the storage hoppers into trucks and taken direct out to the Southern Railway system or to the pier for loading into barges. Five locomotives are engaged in this work.

For local deliveries a loading dock (*Fig.* 6) is used, with a circular concrete road to obviate the necessity for turning or backing lorries.



Pea-Shingle Concrete with Scrubbed Face.

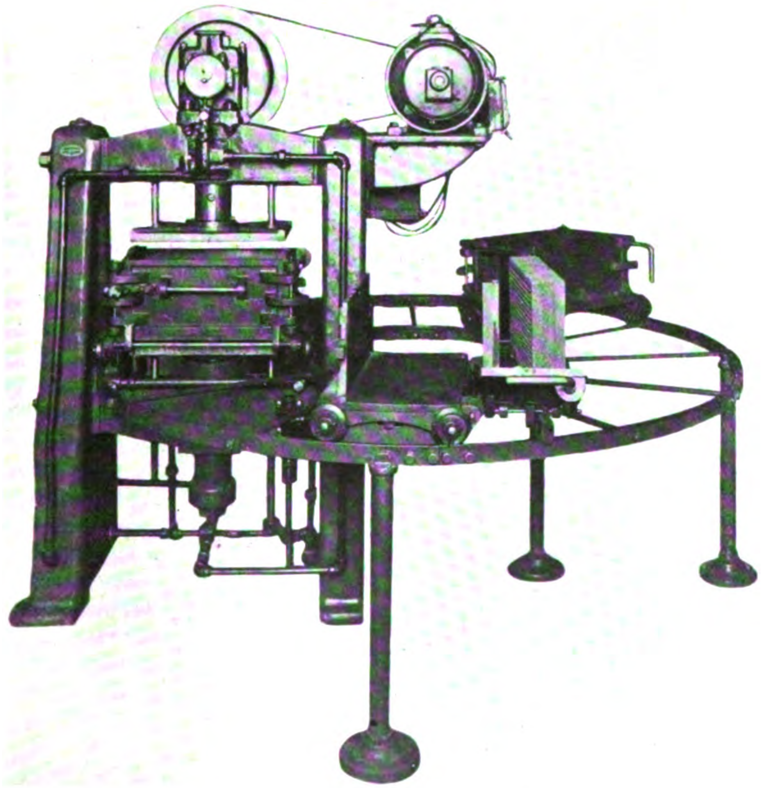
Rapid-Production Block Machine.

A NEW machine for the mass production of concrete blocks and slabs, the invention of Mr. E. G. Enticknap, of Alton, Hants, was shown at the Exhibition of Inventions in London last month. As will be seen from our photograph this is a power-tamping machine in which speed of output is obtained by a circular track for feeding the moulding boxes beneath the tamp plate.

The machine contains several unique features. The contents of the mould boxes are consolidated by a tamper acting at the rate of 700 blows a minute, while the mould-boxes are lifted up to the tamper by hydraulic power.

The operating process is as follows: At a point on the track to the right of the photograph the mould-boxes are filled, preferably from an automatic bin. They are then pushed along the track by hand in the direction of the tamper, that is, anti-clockwise. As they near the tamper an arm on the mould-box actuates a control which lowers the plate on which the moulds are tamped to the level of the track, so that the mould-boxes, which are wheeled, may pass on to it. As the mould-box is pushed exactly in position on the plate the projecting arm actuates another control, which, by hydraulic power, raises the plate containing the mould-box until it reaches the tamper. This distance the mould-box is raised is controlled according to the thickness of the block or slab to be made, or, in other words, the distance the tamper will penetrate into the mould-box.

After the first mould-box has been tamped for the desired period, the second



New Block-Making Machine.

mould-box (which has been filled while the first is being tamped) is pushed along the track towards the tamper. The same controls are operated. Thus, when the arm on the second mould-box comes in contact with the first control, the mould-box under the tamper is automatically lowered, and is then pushed along the track. This leaves the plate clear to receive the second mould-box, which is pushed on to the plate and automatically raised to the tamper as it is pushed over the second control.

This cycle of operations continues without interruption, the raising and lowering of the mould-boxes for tamping being automatically carried out as the following mould-box passes over the controls.

After tamping, the mould-box is pulled along the track clear of the tamper, and by one lift of a handle it is turned on its side and the ends and top opened out on hinges. The block is then on its side, and is removed on plain wooden pallets inserted in the side of the mould-box before filling; this results in the use of one face mould per machine only. The mould-box is then closed and pushed along, ready for filling beneath the materials bin.

When operating at full speed, four mould-boxes are used; while one is being filled, another is being tamped, the third is being opened and the block removed, while the fourth is being closed and made ready to receive another charge of concrete. With the machine illustrated three boxes only were used.

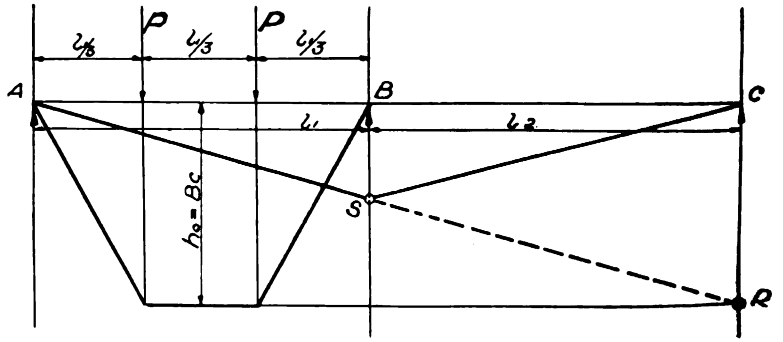
The power required is 1½ h.p., and it is claimed that 22 blocks can be made in five minutes by three men working at full pressure, excluding, of course, the labour employed in supplying materials and carrying away. It is recommended that a belt conveyor or similar means be used of conveying the blocks to the curing ground.

A machine such as this should have great possibilities for rapid output. Except for the carrying away of blocks the whole of the operations are automatic, while the circular track spreads out the operations and obviates the men crowding together around the machine. The idea of turning the mould-box on its side to remove the blocks means that blocks may be made face-down with the use of one face-pallet only, as the thorough tamping received consolidates the concrete to such an extent that the blocks or slabs will stand up on edge and may be removed from the mould without damage.

Blocks made on this machine are being used on the Alton Urban District Council's housing scheme, where 38 houses have been completed in eleven weeks.

Graphical Methods of Calculation.

It is very doubtful whether purely graphical methods will ever be extensively employed in the solution of bending moment diagrams instead of the algebraic, at least in English practice. Nevertheless, in cases of continuous operation, where graphics would be simpler and more suitable, this pamphlet* will be found most useful as well as



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* *Calcul Graphique des Poutres Continues a Section Constante.* By Thomas Kluz, Ingénieur des Ponts et Chaussées, Poland. Pp. 53. 9¾ in. + 6⅜ in., paper cover. Paris: "Le Constructeur de Ciment Armé."

interesting. The whole text is devoted exclusively to the graphical determination of bending moments on continuous and encastré beams of constant section or inertia, together with the algebraic confirmation of each result. It is provided with clear and ample diagrams, and tables of coefficients, which reduce arithmetical work to a minimum. It is written in French, but in a simple and clear style, so that those with but the slightest smattering need not be deterred.

The author claims this method to be new, and for symmetrical loading to be quick and simple in application. This is well borne out by the illustration (Case 3 in the book), which may be summarised as two equal loads P at third points on span l, the left hand span of two unequal spans.

Set up the spans AB and BC and load points and calculate the free moment B_C on span l_1. Make $N_0 = B_C = \frac{1}{3}Pl_1$. Draw TR parallel to AC. Join AR. BS then gives the moment at support B, and the $B.M.$ at any point throughout these spans is immediately available.

Certain systems of loading, of course, require the introduction of modifications; again the case for asymmetrical loading is not so simple and involves the CG of moment diagram areas.

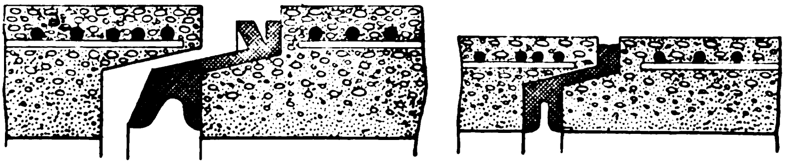
Some two dozen cases are fully investigated leading up, systematically and thoroughly, to the general solution for n spans loaded in any manner. Besides being of use to designers in practice this treatise would form a most excellent study for students and aspirants in their fuller understanding and application of Clapegron's three moment theorem.—L. T.

New Concrete Pipe Joint.

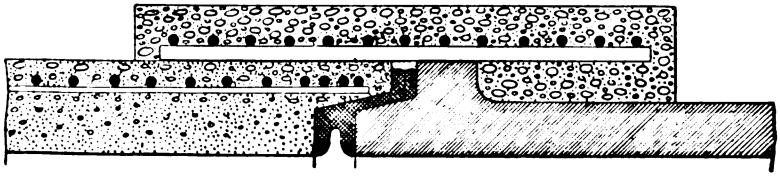
A METHOD of jointing concrete pipes with india rubber has been patented by Mr. Leon Billé, of Nogent-sur-Marne, France.

As is shown in the accompanying illustrations, the pipe sections are lap-jointed with india rubber moulded to the shape shown laid between them. When the sections of pipe are forced together to close the joint a gap remains in the rubber on the inner side of the pipe, so that the water continually presses this part of the joint against the walls of the pipes. It is stated that this joint withstands a pressure up to 284 lbs. per sq. in. without leakage. A joint for pipes 12 in. diameter requires 7 oz. of vulcanised rubber. Owing to the flexibility of the rubber it is claimed that this type of joint will permit of considerable settlement taking place without leakage.

When concrete pipes are jointed to cast iron the connection is bedded in a reinforced concrete collar poured *in situ*.



Method of Jointing.



Joint for reinforced concrete pipe with cast-iron connection: The Concrete Collar ensures Rigidity

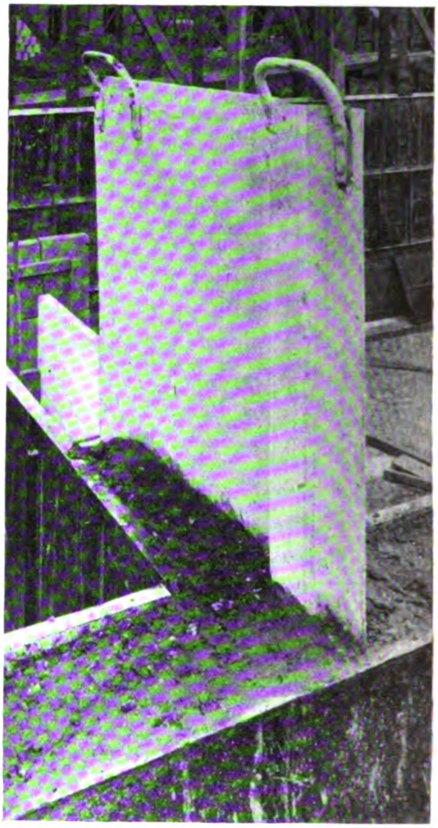
A "Climbing" Expansion Joint.

It is now generally recognised that it is necessary to provide expansion joints between each pair of concrete houses if they are built in blocks of four or more to prevent cracks due to contraction and expansion. The illustration shows the method adopted for forming expansion joints on the 600 concrete houses now being erected at Welwyn Garden City to the designs of Mr. Louis de Soissons and Mr. Arthur Kenyon, FF.R.I.B.A., architects to the Garden City.

After the first few blocks of houses had been built trouble was experienced with cracking. Cracks only occurred in blocks of more than two houses, and took the form of unsightly vertical cracks throughout practically the entire height at about 40 ft. intervals along the wall faces. On this point the advice of Mr. B. L. Hurst, M.Inst.C.E., was taken, and on his recommendation expansion joints are now inserted at each party wall in a block of houses. The joint is ¼ in. wide, and extends 2 ft. from the outer wall face into the centre of the 6 in. party wall.

The method of constructing the joint is clearly shown in the illustration. A steel plate, ¼ in. thick, is inserted within the shuttering at the ground level, and drawn upwards by the handles at the top as the work proceeds. This leaves a complete gap ¼ in. wide through the 8 in. outer wall and extending 16 in. into the party wall, leaving the joint, which is not filled in, showing on the face of the outer wall.

To prevent rain driving in through this gap the joint has two bends within the thickness of the outer wall, so that moisture does not get as far as the porous clinker concrete used for the inside of the wall and for the party wall. Since the adoption of this joint no trouble whatever has been experienced from cracking due to the expansion and contraction of the concrete.

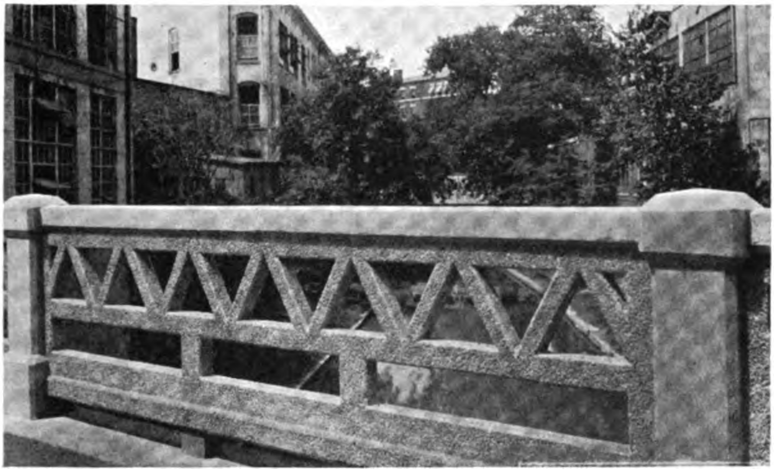


New Method of Exposing Aggregate.

A material which makes it possible to expose the aggregate in concrete without scrubbing or tooling the surface has been put on the market by the Concrete Surfacing Corporation, of New York. The material, known as "Con-Tex," was originated by Mr. N. C. Johnson, of Messrs. Hool and Johnson.

"Con-Tex" is a liquid which is applied with a brush to the inner faces of the shuttering, or on the face of moulds in which concrete products are made, and has the effect of preventing the cement from setting. Thus, when the shuttering is removed the cement which would have formed the surface film may be brushed or rubbed off without scrubbing or the use of acid.

The material is supplied in different grades according to the penetration



Aggregate Exposed by Painting Forms.

required, and it is claimed that it has no deleterious effect on the cement below the depth it is intended to reach. When used for surfacing cement-sand mixes such as are used for architectural cast stone a grade is used which penetrates for a sixteenth of an inch or so, while for exposing coarse aggregate grades are used which give deeper penetrations. If panelled effects are desired, different grades of the material are painted on the forms in accordance with the design, with the result that varying textures are obtained on the surface of the wall.

If the forms can be struck early enough, the material may be painted direct on the face of the concrete, with the same result, but for cheapness and ease of use it is recommended that it be painted on the forms.

Our illustration shows a section of bridge balustrading on which the exposed aggregate surface was obtained by the use of this material.

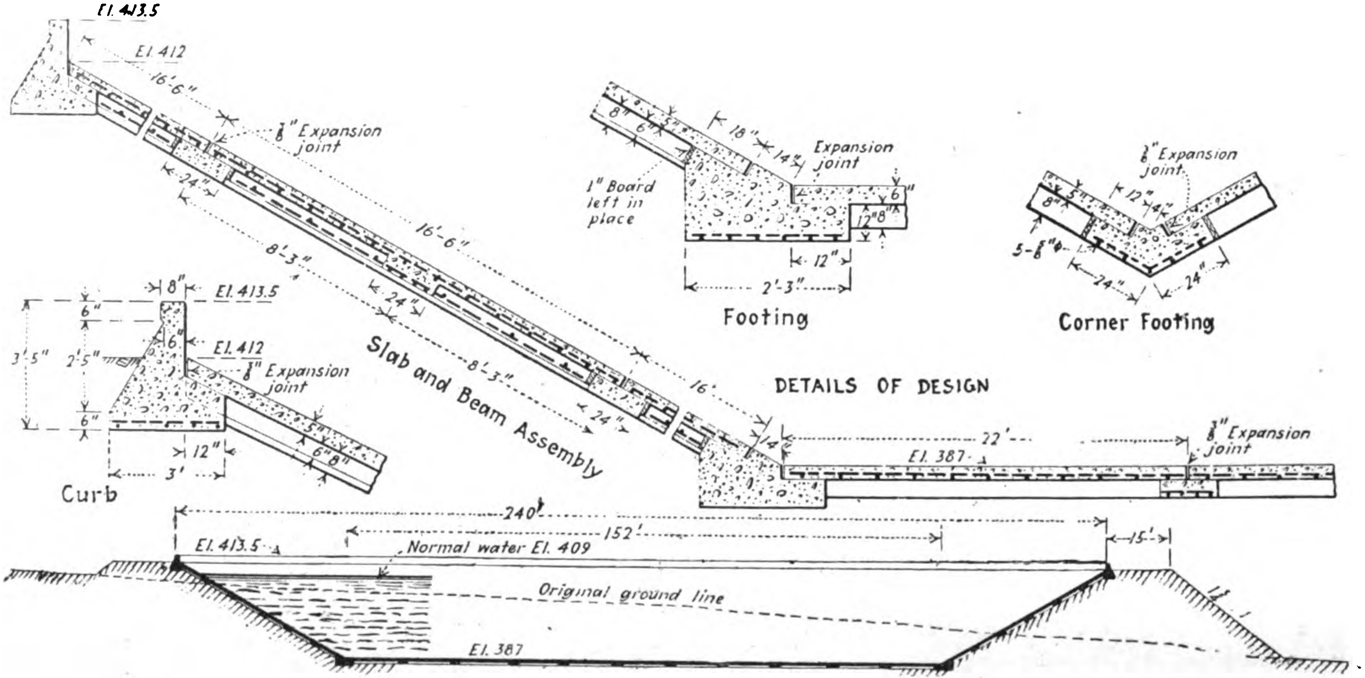
New Type of Reservoir Lining.

REINFORCED concrete slabs poured *in situ* supported on reinforced concrete beams were used for the lining of a 6,000,000-gallon reservoir at Port Angeles, U.S.A. The method of construction is shown in the illustration on p. 752.

The sides have a slope of 1·75 to 1, and are formed of slabs 5 in. thick. The bottom is also formed of slabs, in this case 6 in. thick. The slabs on the sides are 17 ft. square, reinforced with cross ribs on the bottom in order to prevent the slabs from slipping. The bottom slabs are 22 ft. square, without cross ribs.

The floor slabs are separated from the footing beams and from each other by asphalt expansion joints. First the surface of the beams was trowelled smooth and brushed with a priming coat of asphalt, following which about 30 lbs. of asphalt per square was applied at a melting pot temperature of 350 deg.

These notes are taken from an account of the work by Messrs. M. P. Hatcher and E. L. Ferguson, the contractors' engineers, in a recent issue of *Engineering News-Record*.



Typical Cross-Section

New Type of Reservoir Lining. (*See p.* 751.)

Granolithic Floors.

A USEFUL book on "Factory Floor Surfaces" has been issued by the Aberthaw Company of Boston, U.S.A. (price one dollar) which deals with the construction and wearing properties of all the generally used types of floor surfaces for factories, warehouses, and other industrial buildings.

The integral and bonded methods of laying granolithic floors are discussed at length, and their relative merits set out as follows:

Integral finish, being practically part of the structural slab, has the advantage of giving absolute assurance of the surface adhering to the base. There are, however, certain disadvantages from a construction viewpoint, which are in most cases sufficient to make the use of the integral method inadvisable. The principal disadvantage is the possibility of damage to the floor itself. A newly placed granolithic surface cannot be used for at least five days and even then should be protected and must be carefully used. Accordingly, whenever the integral method is employed, construction is delayed until the new floor can be used as a working surface. It is practically impossible to keep the surface from being scratched or marred to some extent because the finish cannot attain a sufficient degree of hardness during the period for which it is practicable to hold up construction. The integral finished floor is likewise subject to damage from rain, hail or frost before it has set, since it is difficult to protect the exposed surface.

When the bonded, or "laid after," method of finish is used, there is no delay to the progress of the structure, as the surface course is omitted and the structural slab is used as a working surface immediately after placing. The granolithic surface is scheduled to be laid at the most convenient time in the operation, usually after the roof is completed, the building closed in and all shoring and constructional material removed. This method ensures adequate protection to the new finish and offers an additional advantage in that any inequalities in the base course, caused by settlement of forms, etc., are taken care of when the finish is laid. There is no necessity for appreciable use of the finished floor for construction purposes and a better opportunity is allowed for the surface to properly harden before the floor is used.

The principal disadvantage in the use of the "laid after" method of placing granolithic is the possibility of imperfect bonding of the surface course to the structural base. Careful preparation of the base and thorough workmanship are essential to ensure bonding. Imperfect bonding is more likely to occur in the case of stairs and other small areas, and for this reason such areas are usually placed integral with the structural base. Good workmanship, however, effectively prevents trouble from this source in any area, large or small.

The method of construction, integral or bonded, may be readily decided upon after considering the advantages and disadvantages of each. Properly laid integral finish should cost less than a bonded finish, the difference in cost being due principally to the necessity for cleaning and preparing the structural base before the bonded finish can be applied. This difference is, however, more than offset by the cost of protecting integral finish from damage and the saving made through quicker progress of the construction as a whole. In general, the advantages of bonded construction have won for it a preference over the integral method.

One of the commonest objections to a granolithic surface is dusting, or the rapid wearing away of the fine material. This condition may be caused by foreign elements in the aggregates, by improper proportioning of the component materials so that the surface contains too great a proportion of cement and fine aggregate, an improper consistency of mixture, or by poor workmanship, particularly overtrowelling which tends to bring the fine material of the mixture to the surface. Because of the better wearing quality of stone, a mixture of 90 per cent. stone and 10 per cent. cement would be desirable if such a mixture were workable. It is, however, a practical impossibility to work a mixture of this proportion, and accordingly the percentage of stone is reduced and a minimum proportion of sand introduced. If the finish is mixed too dry the surface is porous and the aggregates, not being well bonded, will work loose, producing a dusty condition. Finish mixed too wet allows excess water to rise to the surface, bringing up fine particles which wear away quickly. The use of dryers (sprinkling the surface with neat cement or cement and sand) renders the surface dusty because these particles do not bond well with the surface below.

A granolithic floor laid under wholly favourable conditions with the best of materials and workmanship will not of itself dust. That is, it will wear out so slowly that the amount of dust that accumulates is imperceptible. In some cases, however, even a well-laid floor will show a slightly dusty condition when first placed but will become dustless after a few months' use.

Specifications for Granolithic.

Proportioning and Mixing—

Mortar for granolithic finish shall consist of one part Portland cement by measure, one-half part of fine aggregate, and two parts of coarse aggregate. The amount of water used shall be such as will produce a slump of not more than 2 in.

The mixing shall be carried on in a batch mixer and shall be continued two minutes after all the ingredients are in the mixer. Charging and mixing shall proceed in the following order: First, the stone shall be placed in the mixer; second, part of the water; third, the sand and cement; and fourth, the remainder of the water. The whole of the batch shall be discharged before the new charge is introduced.

Integral Finish—

The surface of the base course or structural slab shall be finished by straight edging 1 in. below top of wearing surface. A true surface shall be required; the maximum variation shall not exceed ¼ in.; no finish less than ¾ in. shall be permitted over areas of more than 1 sq. ft. Low areas must be avoided, as excess thickness retards uniform setting of the finished wearing surface.

Any excess water which flushes to the surface shall be removed. Any reinforcing steel which will come within ¾ in. of the finished surface shall be readjusted.

The granolithic mixture shall be spread evenly and straight-edged carefully. Any low or porous places shall be filled and the whole surface again straight-edged.

The entire surface shall be worked over, compacted, and levelled with wood floats before the initial set has commenced.

Before the initial set has taken place, the surface shall be trowelled smooth. The trowelling shall cease before the possibility of damage to the ultimate set has occurred by disturbance of material during setting.

Bonded Finish—

If the finish is to be placed at some period after the base course has set and hardened, the procedure is as follows:

The top surface of the base course shall be 1 in. below the surface of the finished floor, as described under " integral finish."

Just before the base course has attained its final set it shall be thoroughly scrubbed with wire brushes, removing all laitance, fine aggregate, loose material of any kind, and exposing the coarse aggregate.

The surface shall be inspected carefully, all high points removed and then washed clean, covered with coarse sand and kept wet.

Prior to placing the granolithic finish the surface of the sub-base shall be washed free from sand and thoroughly cleaned, using water under not less than 40 lbs. pressure delivered by means of a fire hose if possible, and the slab shall be soaked with clean water until it has taken up all it will absorb.

All surface water shall be removed from the slab, and a mixture of cement and water having approximately the consistency of thick cream shall be brushed forcibly on to the surface just prior to placing the finish material.

Granolithic finish mixed as previously described shall be spread over the surface before the grout sets. It shall be vigorously and forcibly compacted, screeded to a uniform line and grade, and floated.

Before it has attained its initial set it shall be trowelled smooth, using steel trowels and working from a platform supported above the finished surface, if necessary.

Treatment During Hardening—

Granolithic finish shall be protected against rain for 12 hours after being laid, and against too rapid drying out by sun or wind, while setting.

All granolithic finish shall be protected against freezing after laying by maintaining a temperature of not less than 60 deg. for 72 hours.

Granolithic finish shall be covered with sawdust or wood shavings immediately after it has attained its final set and shall be kept thoroughly wet for at least ten days.

Travel of all kinds shall be prohibited over granolithic finish until it is 14 days old. Wheel traffic shall not be permitted for 30 days. Workmen using extreme care may be permitted to step on granolithic which is protected by boards, after 48 hours.

The use of calcium chloride in solution may be permitted, using proper precautions, to regulate the time of setting. Not more than 1 per cent. of the salt by weight of cement shall be used.

A Simple Shuttering.

As the result of experiments with a considerable number of different methods of shuttering for monolithic concrete walls on its Becontree Estate (where several thousand concrete houses are being erected), the London County Council are making extensive use of the "Clements" type, patented by Mr. Jesse Clements, of Northfleet. This type of shuttering is shown in use in *Fig.* 2 (page 756); a frame as it is made up is shown in *Fig.* 1.

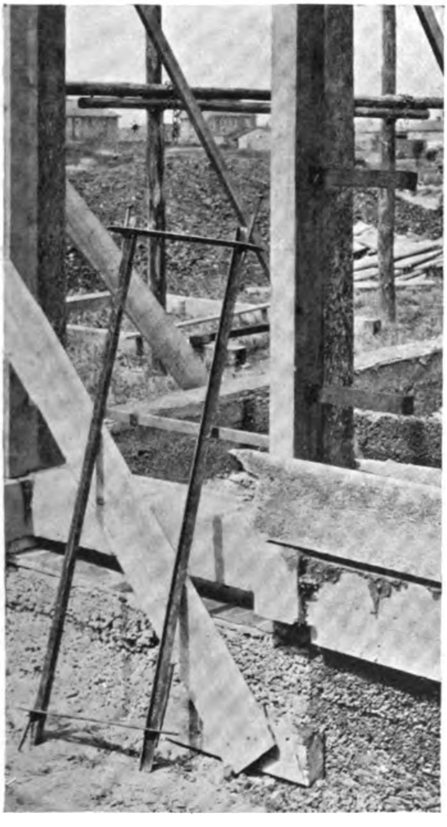


Fig. 1.—Method of Fixing Door and Window Frames to Solid Walls. A made-up Shuttering Frame is also shown.

This shuttering takes the form of 2-in. tee-irons, about 4 ft. long, and metal strips a little longer than the width of the wall. These and a few spikes, are all the equipment necessary to hold the shuttering in position. The metal strips are placed across the footings at intervals of about 5 ft., or less if required by the intervention of wall openings. Through the holes in these strips are passed T-irons about 4 ft. long, and these are firmly held by wedging with spikes. The T-irons are held in position in the same manner at the top. Against the inner (and flat) faces of the T-irons are placed wood planks, forming the shuttering between which the concrete is poured. The shuttering is stripped by removing the spikes and withdrawing the T-irons by lifting them upwards through the holes in the strips.

The lower strips are, of course, embedded in the wall when the concrete is poured, and are removed by knocking them through the wall; this is done by a blow with a hammer at one end and a pull on the other, and is facilitated by giving them a blow to loosen them at the end of each day's work. The small holes left in the wall are made good with cement if necessary, and the faces roughcast outside and plastered inside.

Window and door frames are fastened to the walls by the strips shown in *Fig.* 1; these iron strips are nailed to the wooden frames and anchored into the concrete by the bent-over ends.

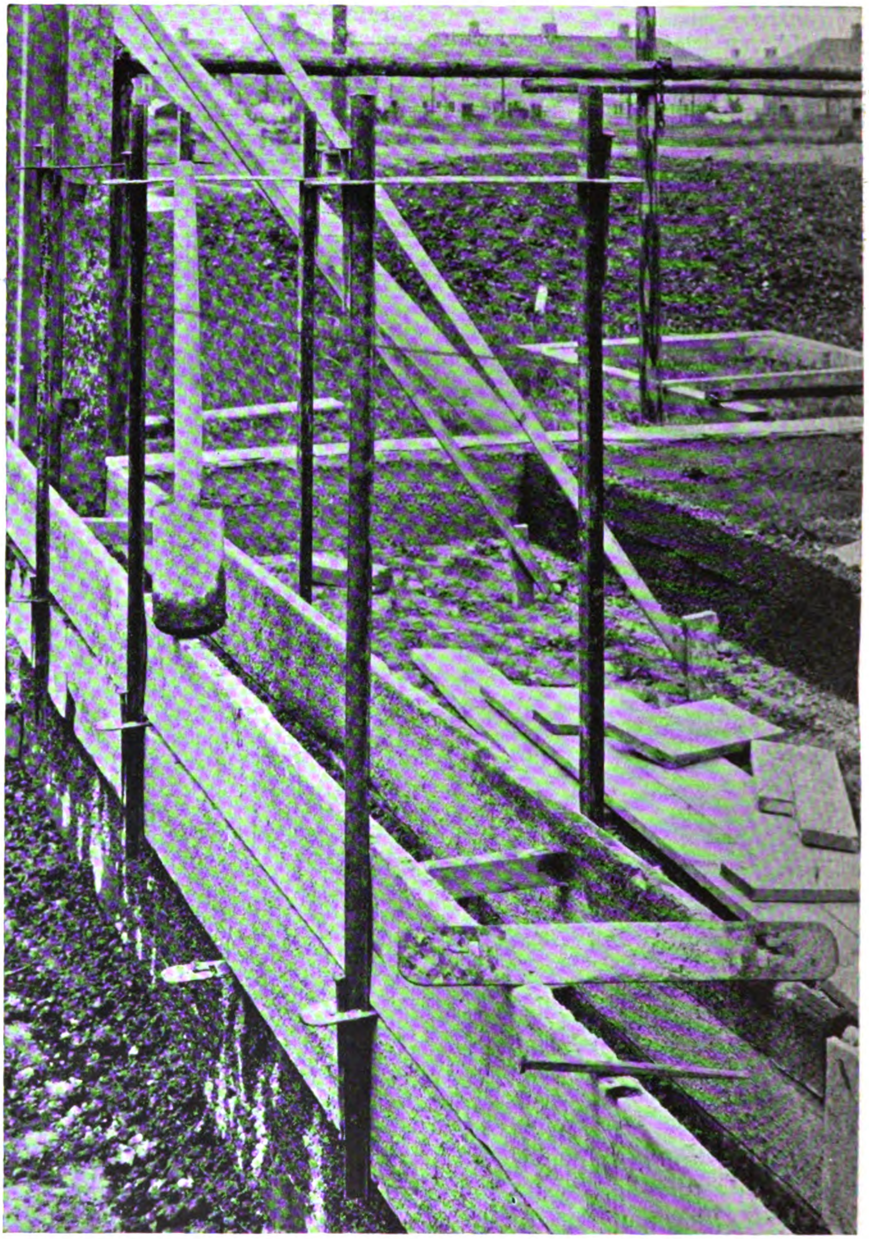


Fig. 2.—Shuttering for "In Situ" Walls: A Distance Piece, Fixing Spike, and Tamper are shown resting on the Shuttering.
(*See p.* 755.)

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

Expansion Joints.

Questions.—(1) I have found difficulty with expansion joints as regards keeping roofs perfectly watertight. Would you state what you consider the best expansion joint, at the same time having a perfectly watertight roof.

(2) I have also experienced trouble with shrinkage of concrete, i.e. where the concrete has been stopped overnight and continued the next morning. I have provided what I have considered to be sufficient temperature bars, but a month or two after completion the joints open up and cause a considerable amount of trouble.—Construct.

Answer.—One of the best ways of keeping a concrete roof watertight in very hot climates, where great freedom of expansion must be allowed for, is to lay the roof in sections, finishing the end of each section with a kind of raised curb with a small space between this curb and the corresponding one on the end of the next section. Rain would be prevented from getting into this space by a reinforced concrete cover-plate extending over the two curbs, and provided with a drip on each side. If the sections are made of such a size that the whole of the concrete in one section can be placed without a break, and in any case not more than 40 ft. or 50 ft. long between expansion joints, it should give a perfectly watertight roof.

This form of construction would also overcome the difficulty in paragraph (2). —O. F.

Proposed Floating Reinforced Concrete Air Ports.

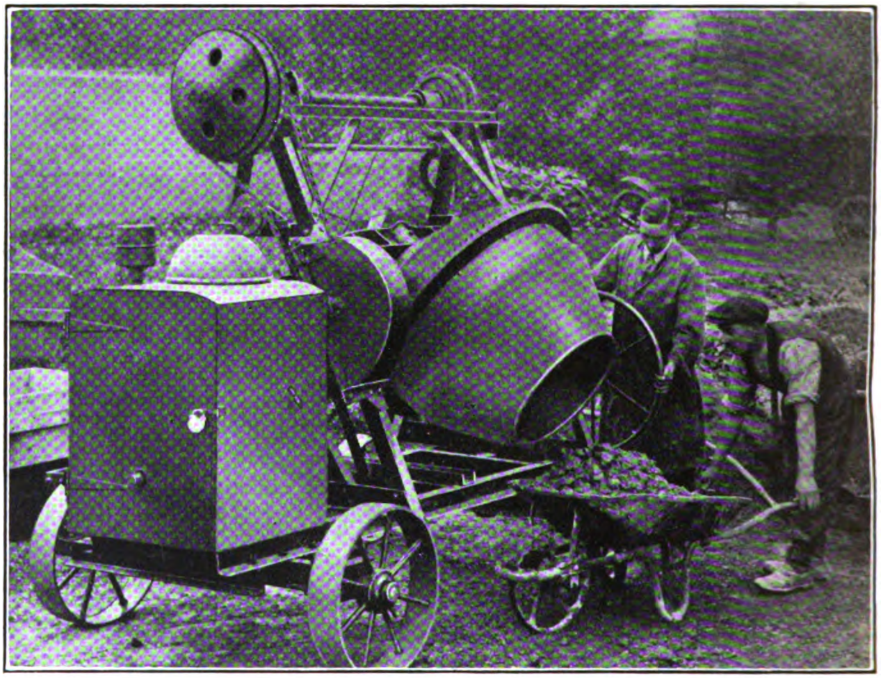
Among the projects submitted to the Imperial Conference was a proposal by Mr. L. Blin Desbleds, of Paris, for the provision of long-distance oversea air routes with island air-ports possessing harbours to provide the reliability and safety needed to make long-distance trans-oceanic air lines of real value.

A set of drawings has been prepared for an island 1,400 ft. long by 755 ft. wide, with a harbour 985 ft. long with an entrance 295 ft. wide. The depth of the harbour, the water of which would rest on the island structure, would be 20 ft. The island would be floating, drawing complete some 80 ft. of water.

It would be built of reinforced concrete, and carry in its lower portion and sides a system of caissons and water-ballasts to ensure equilibrium and flotation at the desired level. Ship-shape, externally, the island would, it is stated, offer relatively small resistance to winds and currents; and it would then be easy to maintain its longitudinal axis always in line with the wind. Made of double the length of a swell in its longest direction, the island would be only slightly liable to pitching; and, since the waves run generally in the direction of the wind it would only in a small degree be subject to rolling. In exceptional circumstances, when the waves presented themselves sideways to the wind, water ballast and gyroscopes mounted on the sides of the floating island would produce the steadiness needed.

A New Mixer.

A NEW mixer has been put on the market by Messrs. Winget (1924), Ltd., with a semi-helix bottom which is claimed to avoid any possibility of the mixing process separating the materials by bringing the large aggregate to the top and the cement and sand to the bottom. The new model is supplied with a batch capacity of 7–5 cu. ft., with a 5 h.p. Lister engine, with elevating hopper, as illustrated; and also with batch capacities of 5½–4 cu. ft., with elevating hopper and 3½ h.p. engine, and 3½–2½ cu. ft. with a 1½ h.p. engine.



A New Mixer.

The mixing-drum of the 7–5 cu. ft. model has a diameter of 36 in., a depth of 33¾ in., and an opening measuring 21½ in., with a speed of 17 revolutions per minute. It is fitted with gun-metal bushes and mounted on a cast-steel trunnion, which is also fitted with gun-metal bushes. Discharge is operated by a tilting wheel controlled by a large handwheel, while the drum is locked in the fill, mix, or empty positions by a simple catch.

The elevating hopper is of the fixed pivot type, power operated. The truck is fitted with 20 in. and 24 in. diameter road wheels and a heavy drawbar. The machine is so designed that an automatic water-measuring tank can be fitted if desired.

The overall dimensions of the plant are 8 ft. 6 in. long by 8 ft. 6 in. wide when the hopper is down, and 5 ft. 9 in. wide when the hopper is up. The height is 7 ft. 10 in., and the net weight 34½ cwt.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d.
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ⅜ in. mesh	„	15	6
Thames ballast	„	10	6
Broken brick (¾ in.)	„	11	6
Best British Portland Cement	per ton 68s. to	73	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	„ 110s. to	115	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £20 „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
7/16 in. to ½ in. Rounds	„	10	9
⅜ in. Rounds	„	11	0
¼ in. Rounds	„	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

				s.	d.
Do.	do.	in foundation	per foot cube	2	3
Do.	do.	in columns	„ „	2	4
Do.	do.	in beams	„ „	2	7
Do.	do.	in floor slabs 4 in. thick	per yard super	7	2
Do.	do.	in floor slabs 5 in. thick	„ „	8	6
Do.	do.	in floor slabs 6 in. thick	„ „	10	8
Do.	do.	in floor slabs 7 in. thick	„ „	11	8
Do.	do.	in walls 6 in. thick	„ „	10	4

(*Add for hoisting* 3s. 6d. *per yard cube above ground-floor level. Add for "Ferrocrete"* 1s. 10d. *per yard cube.*)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
„ 7/16 in. to ½ in.	„	21	6
„ ⅝ in. to 2⅞ in.	„	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½d.; ⅜-in. rods, 1d.; ½-in. rods, 1¼d.; ⅝-in. rods, 1½d.; ¾-in. rods, 1¾d.; ⅞-in. rods, 2d.; 1-in. rods, 2¼d.; 1⅛-in. rods, 3d.; 1¼-in. rods, 3½d. (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1d.; ⅜ in., 2d.; ½ in., 2½d.; ⅝ in., 3d.; ¾ in., 3½d.; ⅞ in., 4d.; 1 in., 4½d.; 1⅛ in., 6d.; 1¼ in., 7d. (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	„ „	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	„ „	1	1½
Do. do. as last, in narrow widths	„ „	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	„ „	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

Adwick-le-Street. — *Houses.* — The U.D.C. proposes to build 270 houses in Doncaster Road.

Aylesham, Kent.—*Concrete Houses.*—A scheme is being considered for the erection of 200 concrete houses for the miners working at the Snowdown Colliery.

Bacup.—*Houses.*—The T.C. has applied for permission to borrow £37,649 for the construction of 54 houses on the Rook Hill estate.

Bampton.—*Houses.*—The U.D.C. has instructed the Surveyor to prepare plans for the construction of 34 houses.

Barnsley.—*Houses.*—Application has been made for permission to borrow £56,876 for the erection of 118 houses.

Basingstoke.—*Houses.*—The T.C. is considering a scheme for the erection of 100 houses.

Bebington.—*Road.*—A by-pass road, estimated to cost £49,500, is to be constructed at Bebington.

Bridlington.—*Sea Wall, etc.*—The Corporation proposes to spend £425 on the construction of a sea wall and promenade.

Cardiff.—*Houses.*—The Corporation proposes to build 145 houses on the Ely estate.

Carlisle. — *Footbridge.* — The Highways and Streets Committee recommends the Corporation to build a footbridge over the L.M. and S. Railway line near Maryport Cottages.

Congleton.—*Reservoir.*—The T.C. has applied for permission to borrow £7,300 towards the construction of a storage reservoir near the Forge Works.

Corby. — *Houses.* — The Kettering R.D.C. has applied for a loan of £14,635 for the erection of 30 houses at Corby.

Cork.—*Bridge.*—The Corporation proposes to build a bridge at Carroll's Dock.

Cork.—*Houses.*—The Corporation proposes to erect 150 houses at Evergreen Road and Curragh Road.

Coventry.—*Bridge.*—It is proposed to construct a bridge to replace the level crossing at Lockhurst Lane.

Crompton. — *Houses.* — The Housing Committee has recommended the U.D.C. to erect 80 houses at Shawside and Smallbrook.

Dartmouth.—*Road.*—The Corporation has applied for sanction to borrow £39,093 for the construction of a road as an extension of the existing embankment.

East Kerrier.—*Houses.*—The R.D.C. proposes to erect 100 houses at Swanvale.

Gravesend.—*Houses.*—The Council proposes to erect 100 houses.

Haverfordwest.—*Reservoir.* — The Corporation has approved of a water supply scheme, which includes the construction of a reservoir.

Hayes.—*Houses.*—The U.D.C. proposes to erect 100 houses.

Hove.—*Houses.*—The T.C.'s housing scheme provides for the erection of 200 houses on the north of Old Shoreham Road.

Kettering.—*Houses.*—The R.D.C. has approached the M.H. for sanction to borrow £14,885 for the erection of 30 houses.

Kilwinning.—*Road.*—The T.C. proposes to construct a road in connection with the Municipal Housing scheme.

Kingsbury.—*Houses.*—The Council proposes to spend £17,100 on the erection of 34 houses.

Limavady.—*Houses.*—The R.D.C. proposes to spend £35,670 on the construction of 103 houses in the rural area.

Lytham St. Anne's.—*Houses.*—Application has been made for permission to borrow money to cover the cost of erecting 80 houses.

Mansfield.—*Houses.*—The T.C. proposes to build 100 houses on the Ravensdale estate.

Middlesbrough. — *Houses.* — The Housing Committee recommends the Council to erect 100 houses on the Whinney Banks estate.

Nelson.—*Houses.*—The T.C. has made application for sanction to erect 110 houses on the Marsden Park estate.

Peterborough. — *Houses.* — Application has been made for sanction to borrow £33,610 for housing purposes.

Pwllpryddog.—*Concrete Bridges.*—The Llandovery R.D.C. proposes to construct reinforced concrete bridges at Chain Bridge, near Broncwrt, and at Pwllpryddog.

Rothwell.—*Houses.*—The U.D.C. has applied for sanction to borrow £42,850 for building 100 houses.

Rushden.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to borrow money for the erection of 122 houses.

SALISBURY.—*Houses.*—The T.C. proposes to build 50 houses at Sheep Fair Field.

SOUTH CROSLAND.—*Road.*—The U.D.C. is considering plans for the construction of a road on the Whitley Beamont estate.

STANLEY.—*Water Tower.*—The Wakefield Corporation proposes to erect a water tower at Stanley.

SWANVALE.—*Houses.*—The East Kerrier R.D.C. proposes to build 100 houses at Swanvale.

TADCASTER. — *Houses.* — The R.D.C. has applied for sanction to erect 100 houses.

TRURO.—*Road.*—The City Council proposes to extend the concrete road from Tregolls Road to Boscowen Street. The cost is estimated at £2,850.

TRURO.—*Houses.*—The R.D.C. has applied for sanction to borrow £16,390 for the erection of 33 houses.

WAKEFIELD. — *Houses.* — Application has been made for permission to borrow £22,000 for building 40 houses in Thornes Road.

WELLINGTON.—*Road.*—A road is to be constructed from Gold Lane to Ercall Lane.

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WEST WITTERING, SUSSEX.—*Groynes.*—The Chichester C.C. proposes to erect groynes at West Wittering.

WESTON-SUPER-MARE.—*Houses.*— The U.D.C. proposes to erect 96 houses in Upper Bristol Road.

WORTHING.—*Houses.*—The Surveyor has submitted plans for the construction of 200 houses.

Tenders Accepted.

CROYDON.—*Concrete Wall.*—The T.C. has accepted the tender of Mr. R. Mansell, at £229 15*s.*, for the construction of a reinforced concrete wall along the boundary site of the Mitcham Road Bath.

DUBLIN.—*Concrete Pipes.*—The South Dublin R.D.C. has accepted the tender of Messrs. H. & J. Martin, at £3,983, for the construction of 424 yds. of 18 in. and 160 yds. of 12 in. concrete sewer pipes. Other tenders submitted were: Fleming Bros., £5,280 18*s.*; Murphy Bros., £6,820; D. Clarke and P. Blake, £4,772 14*s.* 9*d.*; McNally & Co. £4,016 14*s.*

DUNBLANE.—*Bridge.*—The West Perthshire District Committee has accepted the tender of Messrs. Gray's Ferro-Concrete Co., Ltd. for the reinforced concrete work in connection with the construction of Dunblane Bridge.

FRINTON-ON-SEA. — *Groynes.* — The U.D.C. has accepted the tender of Mr. C. H. Jones, Old Road Works, Old Road, Frinton-on-Sea, at £998 15*s.*, for the construction of 16 concrete and timber groynes.

GREENFORD. — *Houses.* — The U.D.C. has accepted the tender of Messrs. John Laing & Son, Ltd., at £101,048, for the construction 168 houses at Greenford.

LONDONDERRY.—*Concrete Wharf.*—The Port & Harbour Commissioners have accepted the tender of Mr. R. Colhoun, of Londonderry, for the construction of a 400-ft. reinforced concrete wharf at Queen's Quay.

LYTHAM ST. ANNE'S.—The T.C. has accepted the tender of Messrs. J. Byrom, Ltd., for the construction of concrete sewer pipes.

NEWPORT, I. OF W.—*Concrete Quay Wall.*—The T.C. has accepted the tender of Messrs. F. Bevis, Ltd., Portsmouth, at £3,361, for the construction of a reinforced concrete quay wall on the east side of the River Medina.

PLYMOUTH.—*Concrete Tubes.*—The T.C. has accepted the tender of Messrs. R. T. Hertop & Co., Mutley, Plymouth, for the construction of 45 yds. of 3 ft. 9 in. by 2 ft. 6 in. concrete tubes.

STOKE-UNDER-HAME.—*Concrete Reservoir.*—The Yeovil R.D.C. has accepted the tender of Messrs. W. Sparrow, Ltd., Martock, for the construction of a concrete covered surface reservoir.

STURMINSTER.—*Sewage Disposal Works.*—The R.D.C. has accepted the tender of the Anglo-Danish Concrete Construction Co., Ltd., at £3,309 15*s*., for the construction of sewage disposal works at Stalbridge.

THURSO. — *Concrete Reservoir.* — The Caithness C.C. has accepted the tender of Mr. J. MacRae, Kildary, at £2,055, for the construction of a 20,000-gallon concrete service reservoir, etc.

VENTNOR.—*Concrete Pier, etc.*—The U.D.C. has accepted the tender of Mr. T. Brading, at £354 15*s*., for the construction of a concrete pier and raft to retain the path near the bowling green at the West Cliffs.

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Recent Patent Applications.

257,332.—R. H. Rogers: Concrete walls.
257,343.—Concrete Ltd., and C. B. Mathews: Concrete blocks.
257,346.—H. Weston: Reinforced concrete slab walls.
257,350.—E. A. Smith: Concrete walls.
258,320.—F. W. V. Fitzgerald: Hydration of concrete.
258,391.—A. Francis and F. Walker: Shuttering.

Trade Notices.

Oil Engines.—At a time when coal is so difficult to obtain, a new catalogue of Messrs. Ruston & Hornsby's vertical oil engines makes a timely appearance. "Ruston" engines are too well-known all over the world to need description here. In one branch of the concrete industry, the supply of aggregates, we found Ruston oil engines installed in the last two aggregate plants we visited, and the manager of one of these works—one of the largest of its kind in the country—remarked that the plant had been in constant use for ten years without giving any trouble whatever. In these catalogues (copies of which may be obtained on application to Messrs. Ruston & Hornsby, Ltd., Lincoln) a great deal of information is given relating to these oil-fuel power units, together with illustrations of "Ruston" engines in use all over the world.

A.C.E. Machinery, Ltd.—The Board of Trade has sanctioned an application of the Australia Concrete Machinery and Engineering Co., Ltd., of Porden Road, Brixton, S.W.2, to change the name of the company to "A.C.E. Machinery, Ltd.," the initials of the old title.

Silicate of Soda.—The Corporation of Middlesbrough has placed a contract with Messrs. David Weston & Co., Ltd., Blackfriars House, New Bridge Street, E.C.4, for the supply of "Concretus" double-layer reinforcement for a number of new carriageways to be laid with concrete surfaces, under the direction of Mr. S. E. Burgess, M.Inst.C.E., Engineer and Architect to the Corporation.

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

DECEMBER 1926 **VOL. XXI No. 12**

TWENTY-FIRST YEAR OF PUBLICATION

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Volume XXI. No. 12. LONDON, DECEMBER, 1926.

EDITORIAL NOTES.

A Notable Concrete Structure.

THE boldness and ingenuity of the leading reinforced concrete designers in France is well exemplified in the bridge now in course of construction at Elorn and illustrated and described in this number. This bridge is particularly notable for the length of its three spans, each of which is nearly 600 ft. in length, or 40 per cent. longer than any concrete arch yet built. The construction of this bridge is involving the use of methods and plant which are engineering feats in themselves, such, for instance, as the aerial cableway of over 2,000 ft. clear span. From the drawings of the project it seems that this bridge will give a complete answer to those who doubt the suitability of concrete from the æsthetic point of view—it would be difficult to imagine anything more graceful, strong, and bridge-like in appearance than this design of M. Freyssinet's.

Architects and Concrete.

THE growing interest of architects in the uses of concrete as a material for the expression of architecture without the usual covering of stone, brick, terra-cotta, or other material, was again shown last month, when the subject was touched upon at the Royal Institute of British Architects by two lecturers in the same week. In a paper on the necessity for new bridges across the Thames, Mr. H. V. Lanchester discussed the relative values of materials from the points of view of cost and appearance, and summed up as follows: " In my opinion all three materials [steel, stone, and concrete] are suitable for town bridges if artistically handled, and, while there may be cases where steel would be out of character with the surroundings, it is difficult to conceive that a good concrete bridge would jar with them, as the colour might be nearly the same as granite or stone, and where cost was a consideration this was greatly in its favour." On the questions of cost we entirely agree ; for it would hardly be an exaggeration to say that 75 per cent. of the new bridges now being built are of concrete because of the low initial and maintenance costs of this material, and what could be more suitable than a concrete bridge across the Thames, the birthplace of the world's Portland cement industry ? Our only criticism is in connection with the lecturer's cautious statement that in appearance such a bridge "might be nearly the same colour as granite or stone," for it could be exactly the same colour. In this statement is summed up the prejudice against concrete on the part of so many architects. It is still thought of as "artificial" or "patent" stone that has to be subjected to some mysterious and camouflaging process to make it look like something else, whereas nothing is further from the truth. This misconception would never occur if architects realised that cast stone or concrete for architectural purposes is simply natural stone crushed to a suitable size and reconstructed with Portland cement. Nothing is hidden or disguised. Rather is the nature and composition of the material revealed by removing the surface cement and disclosing the aggregate behind it. If granite is crushed and used with cement of the right colour the face when tooled will be exactly the colour of granite because it *is* granite, and so on throughout all the natural stones. An architect present asked the object of first crushing the granite and then using cement to bind it together again: the reply, of course, is cheapness. Granite in large blocks is expensive to buy and to shape; if it is reconstructed only chippings, practically a waste product, are necessary, and cutting and carving give way to the much less costly process of moulding the material while it is plastic. Whether poured *in situ* or pre-cast the surface may be tooled by masons using ordinary mason's tools, so that, with good workmanship, it is difficult to discern the difference between natural and cast stone. So far as photographs can show them, we give in this number some of the effects obtainable by using orthodox methods of tooling on concrete surfaces. To get a true idea of the possibilities in concrete surface treatment it is necessary to see actual samples. Many of these are now to be seen on buildings in practically every city in the country, while in a London laboratory is to be seen an extensive range of sample slabs and panels exhibiting the different methods of treatment.

Proposed Products' Association.

THE proposal to form a Concrete Products' Association, given in a letter elsewhere in this issue from Brigadier-General A. C. Critchley, C.M.G., D.S.O., Vice-President of the British Portland Cement Association, should commend itself to all concerned with the manufacture of pre-cast concrete articles. The services such a body could render the industry are clearly set out in the letter, and of its usefulness there can be no doubt. We understand that a large number of manufacturers of pre-cast concrete, including many in a small way of business as well as the large firms, have already agreed to become members, so that if the proposal is carried to fruition the Association should be thoroughly representative. To many it may come as a surprise to know that there are now well over a thousand firms in this country engaged solely or chiefly in the manufacture of concrete products, not counting the innumerable builders' yards where blocks and slabs are produced. It would have been an anomaly if such a growing industry did not form an Association in the near future for its protection, to promote sales, and for mutual assistance, and we wish the present proposal all success.

London's Largest Reinforced Concrete Building.

WORK has now commenced on the foundations of what will be the largest all-reinforced concrete building in London, a tobacco factory for Messrs. Carreras with frontages to Hampstead Road and Mornington Crescent. A perspective drawing of the completed building is given on p. 790. The structure will cost about £500,000 and is scheduled to be completed in about eighteen months. It will be 600 ft. long by 200 ft. deep, with a height of 75 ft. above pavement level. There will be a basement 10 ft. below pavement level and four stories above, with a flat roof. The total floor area will be nine acres. The interior construction will consist of octagonal columns at approximately 17 ft. centres in each direction connected with beams, giving floor slabs 17 ft. square. The shuttering for the walls will be carefully constructed so that there will be no need to plaster the inside of the walls. The front elevation will be relieved with columns and other decorative features in pre-cast concrete, and colour will be used to give emphasis to these decorative features. The architects are Messrs. M. E. and O. H. Collins, of 115, Old Broad Street, E.C., in collaboration with Mr. A. G. Porri, of 37A, Finsbury Square, E.C. The reinforced concrete consulting engineers are Messrs. Considère Constructions, Ltd., of Victoria Street, S.W.1, and the contractors Sir Robert McAlpine & Sons, of London and Glasgow.

Strength of Concrete under Repeated Stresses.

AT a meeting of the Franco-Belgian Association for the Testing of Materials a paper was recently read by Professor Magnel of Ghent dealing with experiments which he has carried out during the last three years on the fatigue of concrete. The method of testing was to use tee-shape sections reinforced in such a way as to fail by shear. Such specimens exhibit cracks on their faces inclined at an angle of 45 degrees in the neighbourhood of the neutral axis. The factor of safety against cracking was found to be only about 1·8, and whether stirrups were used or not the cracks always appeared under the same loading.

In order to produce readily comparable results it is not enough to test only one specimen at a time, consequently a machine capable of dealing with six test-pieces simultaneously was devised. Each specimen was 30 inches long, loaded at the centre of a 26-inch span with 3,300 lbs., the load being put on and removed by a lever and cam which made eighteen revolutions a minute. Machine-mixed concrete was used, carefully rammed into cast-iron forms. The test beams were stored in air in a cool room.

The first visible cracks were observed in a strong light cast on the beam sides. Fatigue cracks were noted at less than 60,000 repetitions, except in the case of the seventh series of specimens, which only carried 63 per cent. of the static load and of which two resisted over 100,000 repetitions. With specimens from twelve to twenty-two months old cracks were always observed for less than 60,000 repetitions of loads varying from 60 per cent. to 80 per cent. of the static breaking loads. One specimen, twelve months old, under 57 per cent. of the static load carried 460,000 repetitions before cracking.

Calcium Chloride in Concrete.

THE use of calcium chloride to prevent the injurious effects of low temperatures on freshly placed concrete has spread rapidly during the past few years, and one result of this practice is that there have been placed on the market a number of solutions, more or less concentrated, of calcium chloride.

A certain amount of caution on the part of engineers is necessary when it is proposed to use such preparations in concrete work, as there is sometimes a danger of deleterious effects.

In *Bâtiment et Travaux publics* M. Anstett has recently given the results of tests of the influence of one of these preparations on mortars made with four different kinds of cements. The particular preparation (" X ") used in these experiments contains 3·8 lbs. of calcium chloride to each gallon of water.

EFFECT ON SETTING-TIME.

Cement used.	Pure water.		1 part " X " to 2 parts water.		2 parts " X " to 1 part water.	
	Initial. (hours.)	Final.	Initial. (hours.)	Final.	Initial. (hours.)	Final.
Aluminous cement . . .	4·10	6·40	0·20	1·05	0·12	0·35
Holderbank	3·00	6·45	0·16	1·20	0·04	0·11
Portland	3·15	6·45	0·15	2·30	0·04	0·17
Slag	3·15	19·00	3·45	11·30	1·45	6·15

Obviously Portland and Holderbank cements cannot be used with a concentrated solution of " X," as the initial set is reached in four minutes. Even with the weaker solution the setting time is less than is allowed for initial set by the British Standard Specification.

EFFECT ON COMPRESSION STRENGTHS OF MORTARS.

Cement used.	Pure water.		2 parts " X " to 1 water.		2 parts " X " to 1 water.	
	2 days.	7 days.	2 days.	7 days.	2 days.	7 days.
	Compressive strength in lbs./in.^{2}					
Aluminous cement . . .	2,880	4,000	2,050	2,060	1,500	2,160
Holderbank	830	2,390	2,040	2,180	1,165	2,040
Portland	282	1,320	928	1,550	610	1,145
Slag	231	720	28	146	28	720
Method of storage of specimens	In water at 59° F.				at – 4° F.	

These tests show that at ordinary temperatures the solution is harmful except to Portland cement, whereas with low temperatures, at which cements gauged with pure water would give mortars of no strength, the solution certainly does improve the resistance of the mortars to compression.—W. S. G.

Reinforced Concrete Quay Wall at Portsmouth.

ANYONE familiar with Portsmouth will remember the old Camber Bridge at the end of East Street, with its narrow and difficult waterway around the sharp corner formed at that point. A great improvement has now been effected by the demolition of the bridge and the removal of the old abutment, resulting in a very smooth and considerably wider passageway round the corner. This improvement necessitated the demolition and reconstruction of the existing quay wall for some distance, and the Borough Engineer, in preparing the scheme, decided upon reinforced concrete as the most suitable material for reconstruction. The special design chosen for the quay wall was that introduced and developed in this country by Mr. R. N. Stroyer, M.I.Mech.E., of Abbey House, Westminster, S.W.1, and described in this journal for November, 1922.

On referring to the typical section of the new quay wall (*Fig.* 1) it will be seen that one of the main features in connection with this design is the absence of all tide work, the whole of the subaqueous construction consisting of piling, and as, in addition, this form of wharf construction provides the maximum of strength and rigidity with the minimum consumption of material, and thus ensures the utmost economy in cost, engineers and wharf owners contemplating reconstruction would do well to direct their attention to this system of construction.

A section of the old quay wall is shown in *Fig.* 2, and the difference in material and labour is at once apparent, as is also the increased protection against scour in the new quay wall and the facility for providing for future deepening of the waterway. The photographs illustrate the work during construction. *Fig.* 3 shows the driving of the raking anchor piles, special steel frame pile drivers with tilting and extending leaders being used. In *Fig.* 4 the wharf is shown with the cofferdam that was necessary for the demolition work, while *Fig.* 5 shows a view of the finished wharf.

The demolition of the existing wharf proved a most arduous and difficult task, as huge masses of masonry and old concrete footings had to be removed inside cofferdams to clear the way for the new

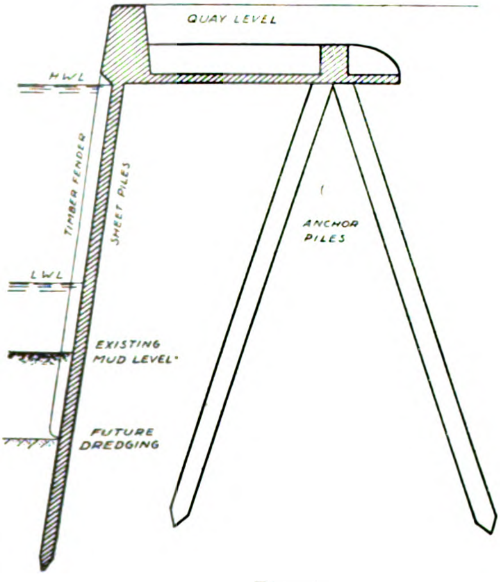


Fig. 1.

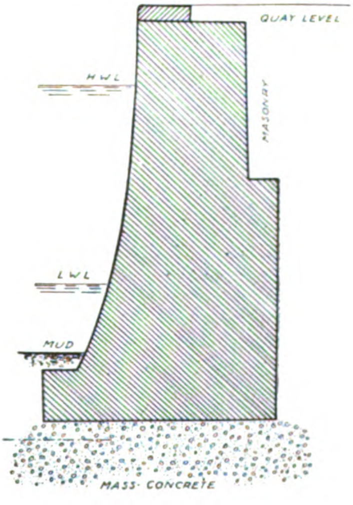


Fig. 2.

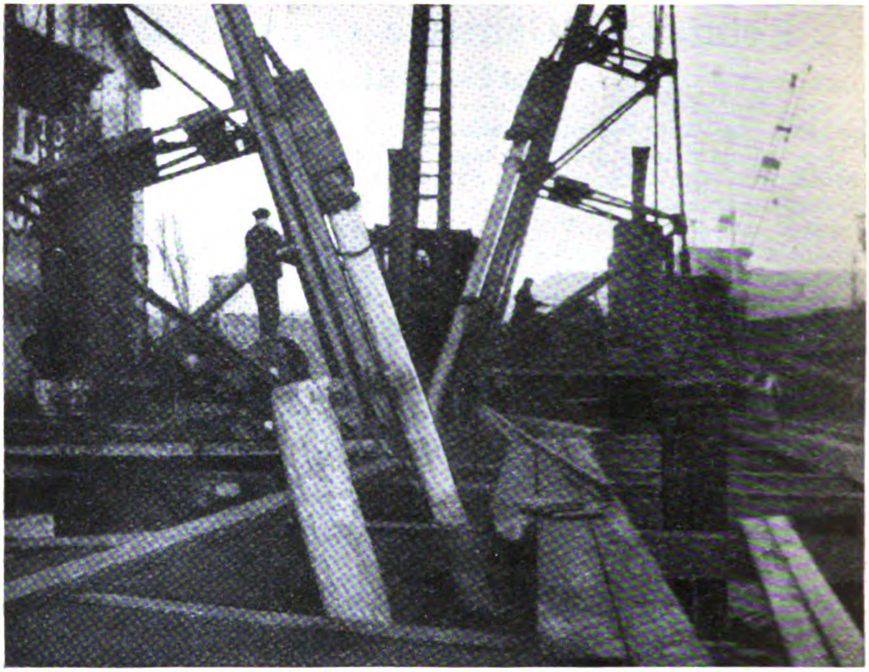


Fig. 3.—Pile Driving.

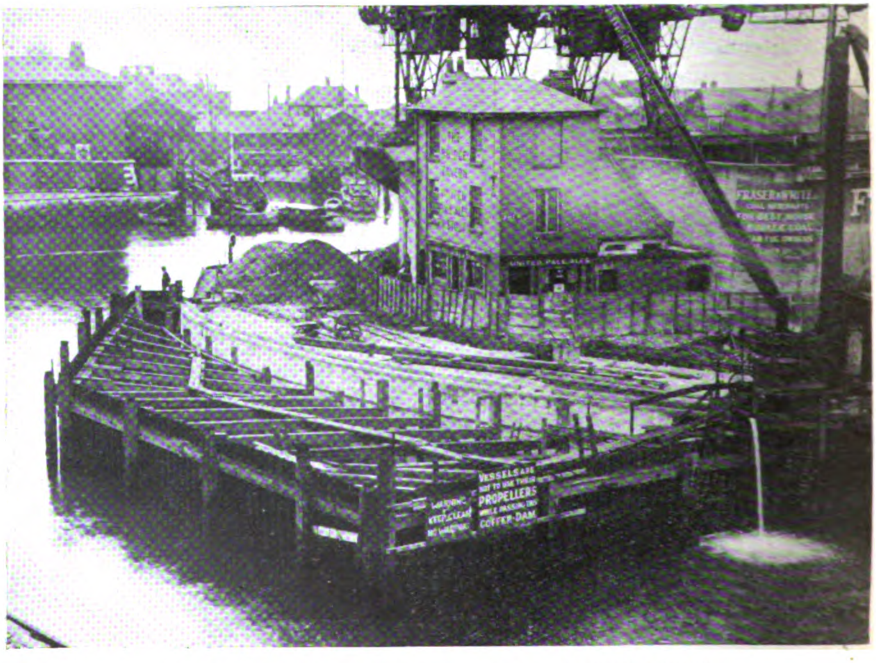


Fig. 4.—Cofferdam for Demolition of Old Wall.

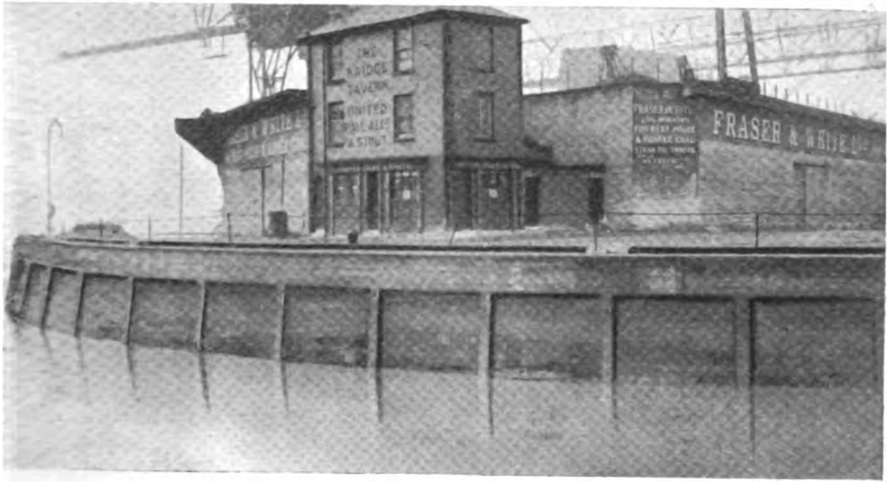
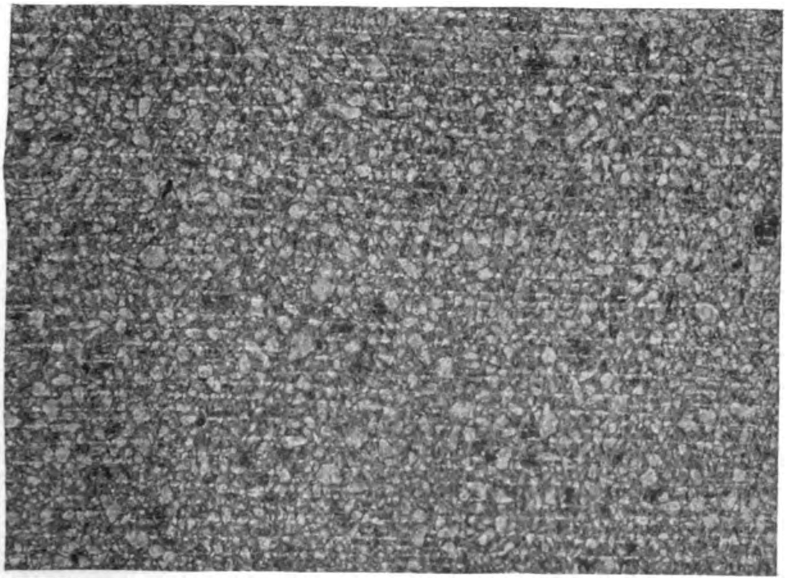


Fig. 5.—The Completed Wall.

work and for a possible future deepening of the waterway. The contractors were Messrs. Frank Bevis, Ltd., of Portsmouth, whose long experience in marine work and special equipment for this kind of construction enabled them to deal satisfactorily with the practical difficulties of the work.



A Tooled Finish with Selected Aggregate. (*See p.* 793.)

Formwork for Walls and Columns.

It is well known that formwork is a costly item in reinforced concrete work owing to the limited number of times which any piece of timber may be employed, and the removal of nails, which are too often fully clenched. Any invention tending towards the reduction of shuttering costs is worth attention, and for this reason we reproduce drawings from *Revue du Beton Armé* illustrating a framework for supporting formwork which has been invented by M. Pierre Lesca.

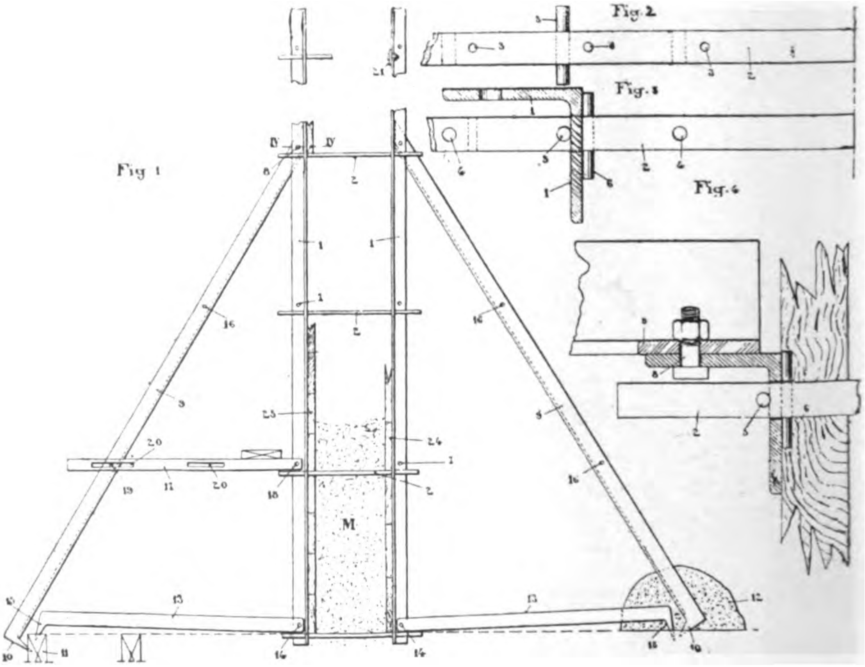
The outstanding feature of this invention is the ease with which the framework may be erected and dismantled. This is obtained by the simple joint connections shown in *Figs.* 1, 2 and 3.

Fig. 1 shows in diagrammatic fashion a vertical section through the formwork for a simple straight wall. The main vertical members, which may be angle, tee, or channel iron, occur in pairs and are stayed at intervals with flats. The lower portion of the frame is anchored to the ground by the members 13, and wind-bracing is provided by the members 16, which also serve to support the cross-stays 17 supporting the working platform. Details, to a larger scale, of the joints, are shown in *Figs.* 2 and 3. A horizontal section at the junction of the main vertical member and the wind-brace is depicted in *Fig.* 4.

The invention deals simply with wall corners (*Figs.* 5 and 6) which are strongly braced, and with columns (*Fig.* 7). By having a series of holes punched at the ends of the members 2 the vertical angle-irons may be spaced at different distances apart, thus giving support to columns of various dimensions or walls of different thicknesses.

The vertical members will normally be placed about one yard apart in wall work. For high walls the verticals consist of two angles riveted back to back or with a plate between them. The cross-stays are placed at such vertical distances apart as will suit the commercial sizes of timber.

The framework is claimed to be very rigid and ought to facilitate the alignment of walls.—W. S. G.



Rapid Concrete Construction.

Novelty in design and rapidity of construction, with frequent tests to ensure good concrete, are, says " Engineering News-Record," interesting points in a 19-story reinforced concrete apartment building erected in Chicago. The building is **T**-shape in plan, 120 ft. deep, with the two ends 60 and 136 ft. wide and with the narrower stem thirteen and sixteen stories high, while the wider portion has nineteen stories. Its total floor area is 195,000 sq. ft.

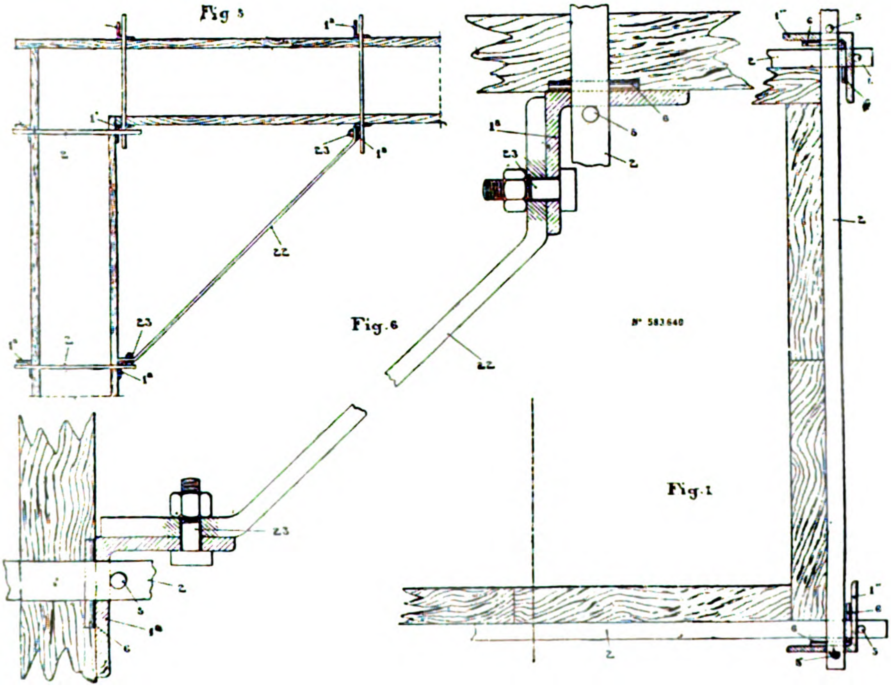
Reinforced concrete is used throughout, with a framing plan made irregular in order to fit the lay-out of the architectural design, so that the column spacing varies from 16 to 22 ft. To secure a minimum of obstruction the columns are arranged mainly at the junctions of partitions; the largest columns are 24 in. by 40 in. and 16 in. by 64 in., each with about 40 sq. in. of steel bars. All floors are designed for 40-lb. live load. The story height is 10 ft. 3 in., increased to 13 ft. 3 in. for the twelfth and nineteenth stories and 18 ft. for the basement.

A 36-in. foundation slab covering the entire area is designed for a soil bearing of 3500 lb. per sq. ft. Reinforced concrete curtain walls built monolithically with the first floor spandrels and extending down to this slab enclose the basement. In the floor slab are embedded the electric conduits and plumbing pipes, as well as hangers for carrying other piping between the joists.

Excavation was started on March 14, 1924, and the concreting of the foundation on May 1. From the accompanying table of progress it will be seen that the twelve

Dates of Completing Floor Slabs.

Foundation	May 5	Floor	
Floor		10 . . .	June 17
1 . . .	May 15	11 . . .	June 18
2 . . .	May 23	12 . . .	June 21
3 . . .	May 27	13 . . .	June 23
4 . . .	May 31	14 . . .	June 26
5 . . .	June 3	15 . . .	June 28
6 . . .	June 6	16 . . .	July 1
7 . . .	June 9	17 . . .	July 3
8 . . .	June 12	18 . . .	July 8
9 . . .	June 13	19 . . .	July 20



(*See p.* 770.)

stories above the fifth floor were placed in a month, or at an average of about three floors (10,000 sq. ft. each) per week. After the eighteenth floor had been completed there was a delay of two weeks.

Wood forms for the joists were built on the work and were reused three to five times on an average. The type of shore used had a 4 in. by 4 in. stick for the top section, sliding in a cast-iron collar on a lower section composed of four angles fitted with supports of 6-in. intervals to hold a short cross-bar of I-beam section. Accurate setting or adjustment was effected by means of a jackscrew in the base. This construction facilitated the setting up and removal of floor forms. With the practically uniform story height, sectional wood column forms, which were reused four or five times, simplified the form erection problem. Weather conditions were favourable, although rain interfered with the finishing of the floor slabs.

The main construction plant consisted of a ¾-yd. concrete mixer with electric motor, a 1-yd. concrete skip elevator, two platform elevators for brick, tile and other work, and two self-dumping skip elevators for steel rods, form timber and woodwork. All the elevators were operated from two triple-drum steam hoists. Other equipment included pumps, several small gasoline-operated concrete mixers and a wood-working outfit in the carpenters' shop. An adjacent two-story building housed the construction office, timekeeper's office, repair shop and tool storage. The main concreting was done with the large mixer, located in an angle of the building, together with the towers for concrete skip elevator and material cage elevator. Concrete aggregates were dumped in storage piles and delivered by wheelbarrows to the mixer, where the cement was added. To facilitate charging, the mixer was placed below street level and the skip dropped below the mixer. At the top of the tower, the skip dumped the concrete into a 1½-yd. hopper, the flow from which to the chutes was regulated by a man on the hopper platform, who also signalled to the mixer crew. Two 50-ft. lengths of chutes were suspended from cables leading from the top of the tower to the corners of the building.

To ensure a good quality of concrete and avoid any chance of defective material due to rapid progress, frequent slump tests were made by the architect's superintendent, while a testing company took samples of the concrete from each tier of columns and each floor slab. Compression tests on cubes made from these samples are said to have shown a higher strength than that required by the Chicago building code for the mixtures used, which were 1 : 1 : 2 for columns and 1 : 2 : 3½ for slabs. The cost of this inspection and testing is said to have been considerably less than 1 per cent. of the cost of the cement used.

The building was designed by Messrs. Fugard & Knapp, architects, Chicago, with Mr. Samuel Klein as structural engineer. The general contract was let to the McLennan Construction Co. With a total cost of about $1,250,000 the unit cost is given as 62½c. per cubic foot, or $6.40 per square foot of floor area.

Reinforced Concrete Bridge at Elorn, Brest.

ARCHES OF 600 FT. CLEAR SPAN.

BY LESLIE TURNER, B.Sc., A.M.Inst.C.E.

THE construction of this bridge is now well in hand, and as it will constitute a notable achievement not merely in the history of reinforced concrete alone, but also in realms of general constructional engineering, it is here described at some length. In the matter of clear span alone it surpasses by some 40 per cent. anything hitherto attempted in France, and by 50 per cent. in England and America, so that the problems presented and the solutions adopted, with particular reference to the actual erection, are worthy of more than passing attention.

Some illustrations and particulars were given in a previous issue (*C. & C. E.*, Vol. XIX, No. 6, June, 1924), when it was announced that a proposal had been definitely accepted. This information related to project drawings and will be reproduced where necessary. Fig. 1, taken from a proposal sketch, gives an idea of the monumental proportions of the bridge and displays the simple straightforward treatment of the design, resulting in a structure of great beauty and grace. As will be observed, every member fulfils an engineering function; there is no redundant decoration.

General.

The object of the bridge is to link Brest both by rail and road with Sizun, Quimper, and South Brittany by a more direct route than the long detour via Landerneau at present necessary. There is a ferry at Le Passage, a mile or so higher up than the new bridge, but this naturally involves much delay. At each end a new road is being cut so that there will be a direct route for vehicular traffic from Brest to Plougastel, Daoulas, Sizun, and thence on to the south. In addition, the bridge will carry a railway track of standard gauge, thus linking up the railways on each side of the river.

The construction was authorised by the *Conseil général du Finistère* in collaboration with the *Administration des Ponts et Chaussées* (the equivalent of our Roads Department, Ministry of Transport) and the local authorities. Each party bears a proportionate share of the cost as it would do in England.

Eight French constructional firms submitted schemes, three for steelwork and five for reinforced concrete. The tenders for the former ranged from 11,360,000 to 13,776,000 francs, and for the latter from 7,340,000 to 16,170,000 francs according to the accommodation offered. After thorough consideration one of the reinforced concrete schemes was adopted, providing a double deck having the roadway above and railway below, and adequate waterway, at reasonable first cost; a particular point favouring the choice of concrete, beyond that of æsthetic superiority, was its negligible maintenance charges.

The tender accepted was that presented by l'Entreprise Limousin et Cie, of Paris, who submitted prices on the designs of Monsieur E. Freyssinet, who is well known as the designer of the Orly hangars and the St. Pierre du Vauvray bridge over the Seine. The contract involved about 11,000,000 francs and a guarantee of entire responsibility for ten years. The cost, of course, cannot be translated into English currency by dividing the above figure by the rate of exchange then ruling, as so many factors additional to the lag in the rise of cost of materials and labour enter into the question. At a venture, for which no responsibility is taken, the writer would put the cost at £200,000 at the very least (assuming similar circumstances in the British Isles), but it is more than probable that rates of labour here and our innumerable restrictions would increase this figure very considerably.

The constructional period was stated to be three years.

It is with much pleasure that the writer would here express his thanks and appreciation to MM. Limousin et Cie. and Monsieur Freyssinet for their kindness in supplying the bulk of the information, for the presentation of many of the photographs reproduced herein, and for permission to publish them.

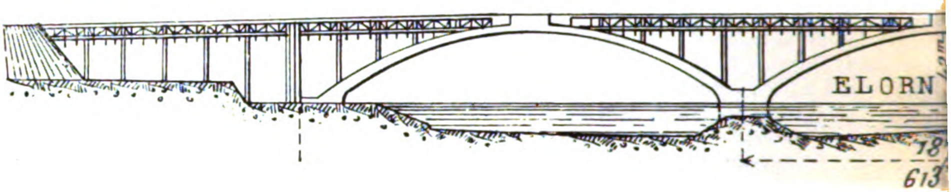
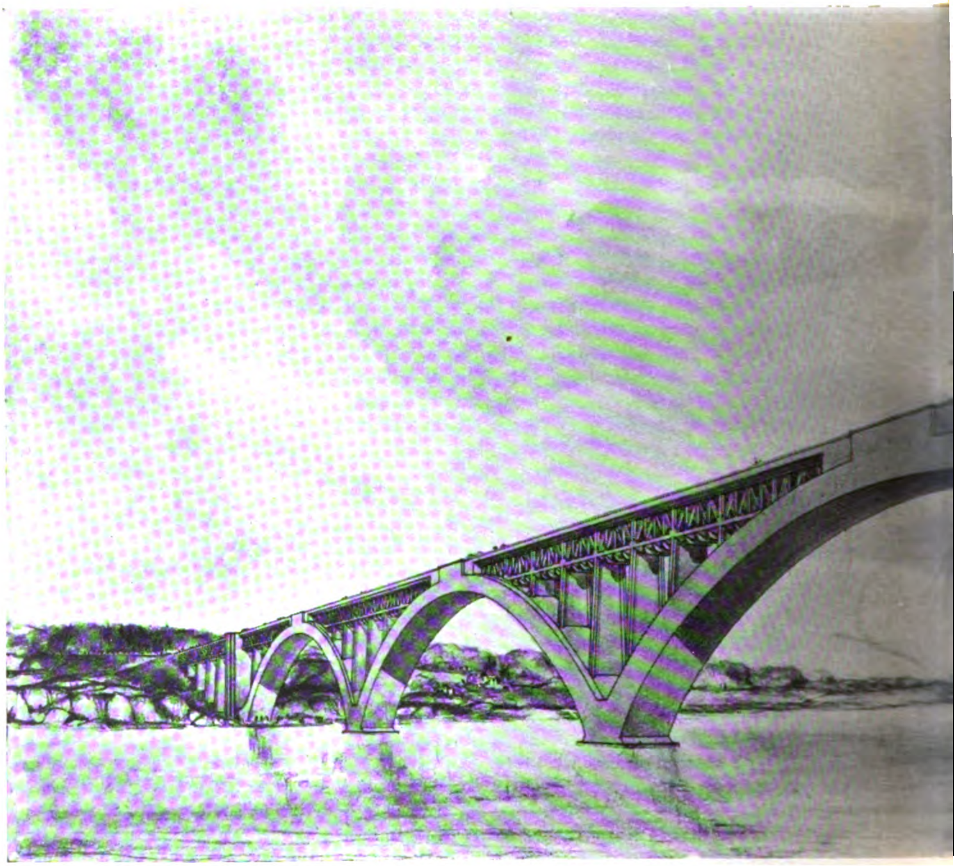
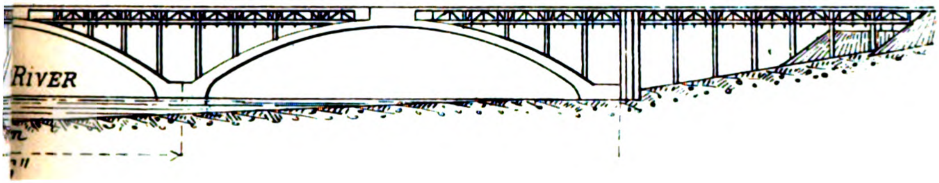


Fig. 2.



REINFORCED CONCRETE BRIDGE AT ELORN, FRANCE :



evation.

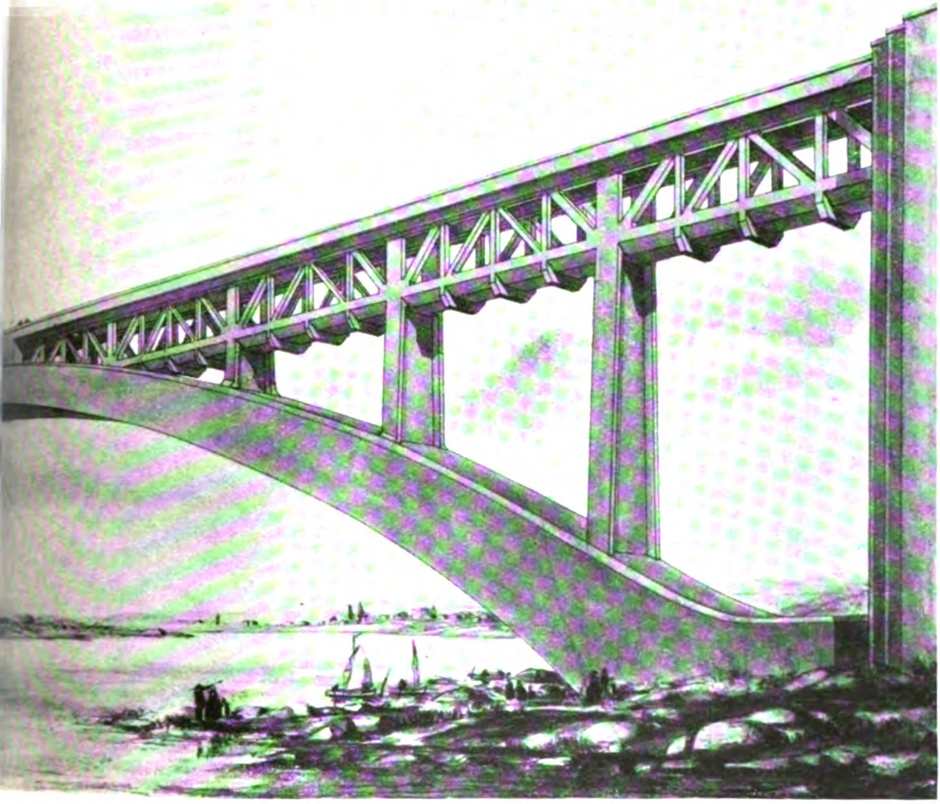


Fig. 1.—PERSPECTIVE DRAWING OF FINISHED BRIDGE.

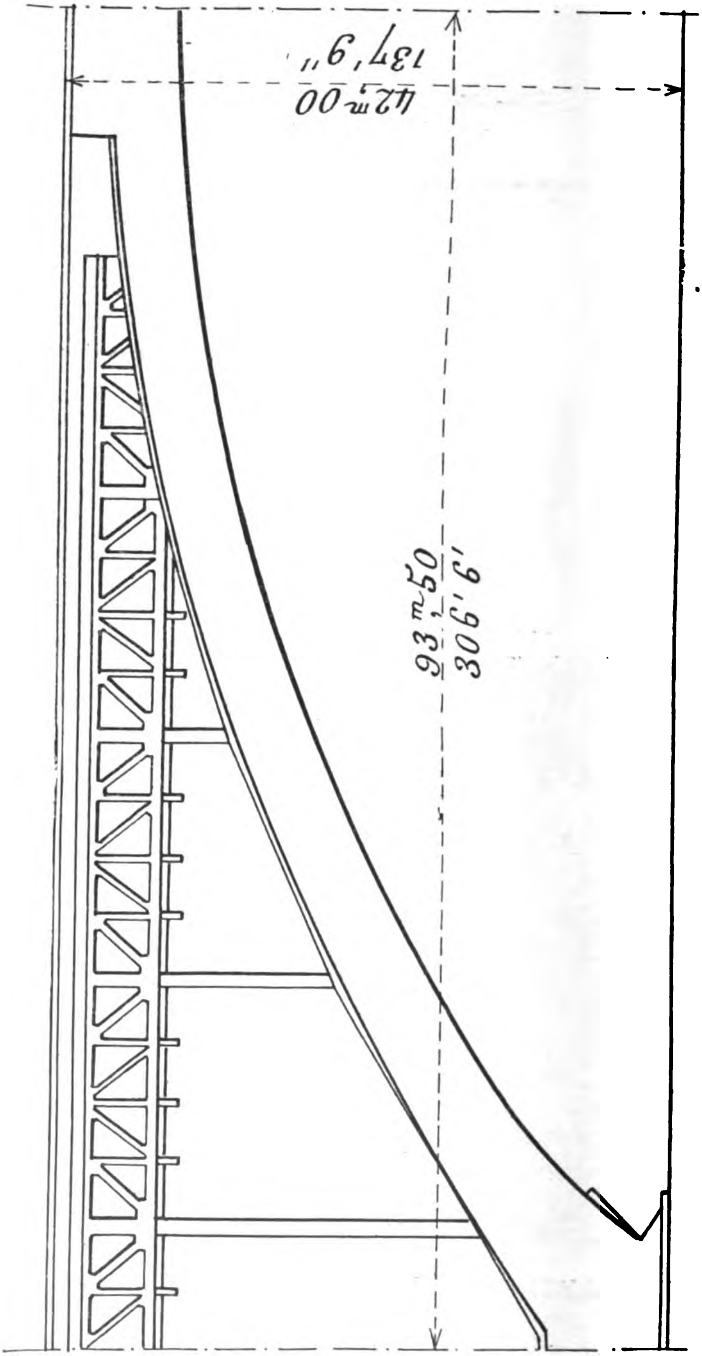
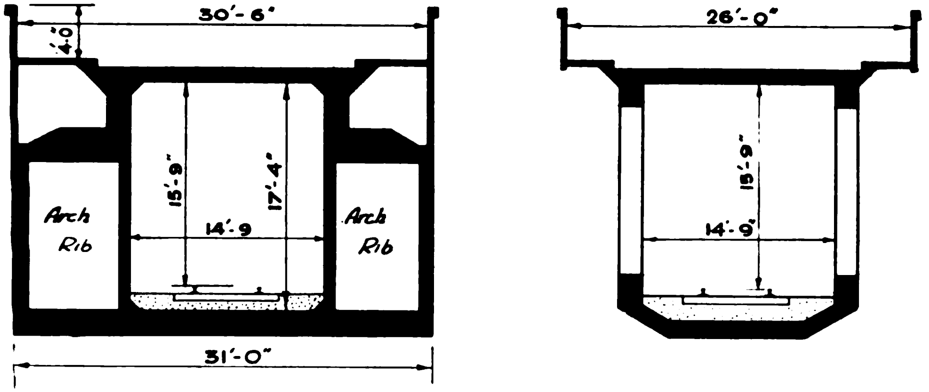


Fig. 3.—Half-Elevation of Arch Rib.



SECTION AT CROWN.

SECTION OVER SPANDRIL.

Fig 4

Site.

The site is located about 5 miles due east of Brest, Finistère, France, at a spot where the Brest Roads, forming the mouth of the river Elorn, narrow down to between one-third and one-half mile in width, i.e. about 1 mile N.W. of the village of Plougastel. To the west the bridge is open to the uninterrupted fury of south-westerly gales, while variations between high and low tides in this vicinity are amongst the biggest in the world.

By way of advantages, however, the banks rise fairly rapidly to high ground on each side of the estuary, so that ample rise at crown of arches is obtained without long approaches or heavy gradients. With regard to raw materials the entire locality is made up of hard Devonian strata or igneous rocks, chiefly granites, with numerous dykes of quartzites. The latter yield perfect coarse aggregate, while sand is naturally easily available. The port of Brest and the railway render other materials easily accessible.

Description of Bridge.

As will be seen from *Fig.* 2, the bridge will consist of three similar arches, each of 590 ft. 6 in. span, supported on two piers in the river and on two abutments on the banks. There will be an approach viaduct about 427 ft. long, ranging from 140 ft. in height down to zero at each end. The overall length of the bridge will be about 2,625 ft., a few feet short of half-a-mile.

The clear width of roadway, measured over the cantilevered footpaths, is 26 ft. widened to 30 ft. 6 in. over centres of spans, and its position with relation to the railway is shown in *Figs.* 3 and 4. The braced truss below the road has internal clearances of 17 ft. 4 in. by 14 ft. 9 in. to accommodate the single-track 4 ft. 8½ in.-gauge railway.

On each side of the railway two arch ribs rise and carry the lattice girders on piers in the spandrils and directly at their crowns. The arches are about 613 ft. span centre to centre of piers, with a radius of curvature of 460 ft. and a rise of about 115 ft. They are rectangular in section and hollow from the springings upwards, and, as will be noticed, the floor and roof of the arch rib are thicker than the walls.

The abutments are solid, and consist of prolongations of the arches (as shown in *Fig.* 1) except that the horizontal terminal is being deleted. Both the abutments and piers will rest on solid rock, to attain which the bases of all of them have to be taken well below low-water level. At low tide the maximum depth of water is about 53 ft., but it can be seen that the piers occur at advantageous positions on the cross-section of the estuary, although even then there is a depth of 30 to 40 ft. of water to deal with.

Again, these piers are designed to act as abutments so that one arch may be erected and the centres struck before the adjacent rib is even commenced. The

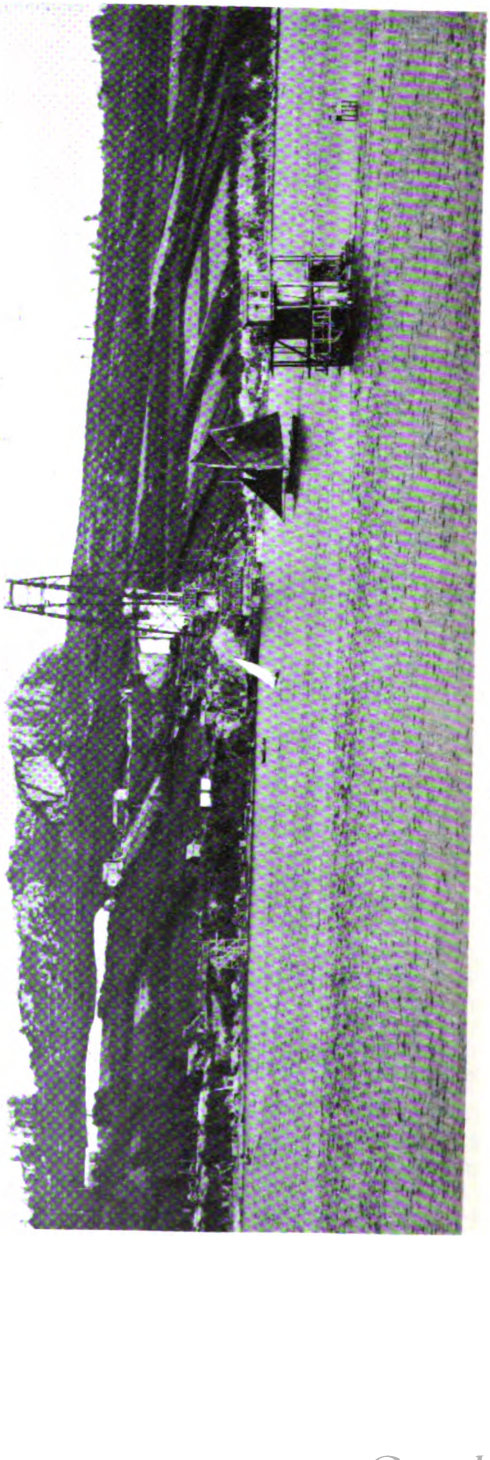


Fig. 5.—General View of Site, Looking South.

local conditions of navigation and river currents, and the exposed position, render the use of intermediate supports to the arch shuttering very undesirable, so that a single-span latticed arch will be assembled on the foreshore, floated out, and supported on temporary skewbacks to bridge the whole 600 ft. at one bound, thus forming the support for the permanent work. The temporary span can then be moved sideways into position for concreting the second rib to the same span, or conveyed to the other spans of the bridge and the process repeated. Concrete will be taken out direct at the shore end and conveyed by aerial ropeway to the piers.

The job will consume some 26,000 cubic yards of concrete and 1,200 tons of steel bar reinforcement.

Temporary Works and Plant.

Operations were commenced about twelve months ago, and an immense amount of preliminary work has now been completed. It will be readily appreciated from the foregoing that, as M. Freyssinet remarked to the writer on the site, the difficulties of actual construction of this project far overshadowed the problems of the design and computation of the permanent structure, serious and intricate as these may have been.

Fig. 5 shows a view taken in August from the north bank looking south. The caisson in which the north pier is being constructed can be seen, together with the aerial cableway of over 2,200 ft. span, behind which the south approach is turning left to join up with the proposed new road. The railway track, on the other hand, will sweep off to the right so that the viaduct piers are not pierced to take it. The workshops, hutments, quarries, stores, power units, etc., are situated on the south bank and occupy many acres, extending some half a mile along the road.

The labour is mostly French, and those imported for this job are housed in a colony of huts complete with café. It is interesting, not to say significant, to remark here that at the present time labour is scarce and at a premium in France, so that foreign workmen, up to sometimes 50 per cent., have to be taken on. On this contract only 10 to 15 per cent. are foreign—nevertheless, despite these facts and an 8-Hour Act (lengthened to 9 hours during summer) men will not sign on unless allowed to work one hour longer than these limits. The comparison of this spirit with that of our trade unions under similar circumstances requires no further comment.

Next in sequence come the quarries, where excellent quartzite is blasted, then run in trucks to the crusher and screens for grading. It may be mentioned here that a fair proportion of the fine stuff from the crushed stone is being used with natural sand for the concrete. Usually this proportion is half of finely-crushed quartzite to half of sand.

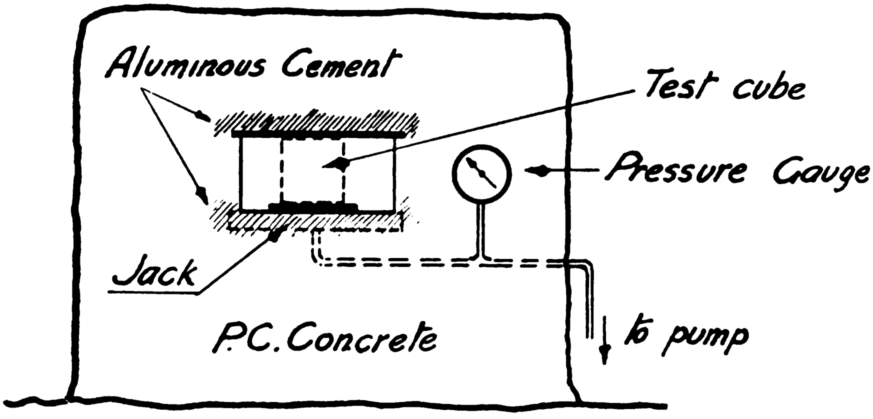
The usual workshops and plant, such as smithy, saw-mills, carpenters' shops, turning and fitting shops, power-house, compressors, stores, etc., have been installed, together with drawing office and a lorry and ferry service.

Testing Shop.

Of particular interest is the small hut that has been erected for the purpose of testing the concrete on the site, its chief feature being the home-made cast *in situ* testing machine. This consists of a block of Portland cement concrete in which a rectangular hole has been left at the centre to allow the insertion of test cubes. The hole is faced with an iron plate set in aluminous cement at the top, while at the bottom a hydraulic jack is let into similar material. A pump and pressure-gauge complete the equipment, as shown on the rough sketch in *Fig.* 6. This machine measures the crushing load on the standard test cubes of 7·9 in. sides.

Experiments have been carried out here to determine the most economical proportions of stone, sand and cement to produce concretes of the ultimate strengths specified, while test cubes are made from pourings as the work proceeds and are tested by this machine as a check on the finished product. The mixtures of the concrete used and their strengths are dealt with later. This improvised testing machine, although inexpensive to construct, is quite efficient in action and adequately fulfils its purpose.

In addition to this, the writer observed many other novel applications of concrete to machines and gear hitherto more



TESTING MACHINE Fig. 6

or less sacred to iron, steel or the harder alloys. For instance, he discovered a battery of hand winches the bulk of the composition of which was concrete. The handles, axles, cogs, and brake-bands were, of course, of iron, but the wheel fillings, major portion of frame, and winding drums were of concrete. Pulley wheels have similarly been cast and successfully employed. These details alone are sufficient to open up a large field which has not hitherto come under the purview of the concrete engineer.

Aerial Cableway.

Although the cableway, or transporter, is a subsidiary structure and forms but a means to an end, it will be acknowledged an engineering feat in itself. It is to be seen on several of the accompanying illustrations. The masts, or towers as they might be termed, are duplicated on both banks, each one carrying one bearing cable. They weigh about 40 tons each, and are composed of timber bracing and laminated timber legs about 180 ft. high and spreading from a point at the top to about 24 ft. at their bases, where they come down on to aluminous cement concrete terminals. These gather the thrust and transmit it through the pin to the casting below, forming composite concrete and steel hinges or rockers, which are clearly shown on *Fig.* 7.

The masts were assembled on the site, in a horizontal position, their bases in their predestined places on each shore with their heads pointing outstream directly towards their counterparts on the opposite bank. This necessitated the construction of a temporary timber platform seen under the partially raised masts in *Fig.* 8. After the four had been completed they were elevated by means of cable tackle and winches operated by man power. A set of smaller fabricated timber shear legs can be clearly discerned in the background, whereby the initial lift was given to the heads. After the completion of this operation the temporary inclined stays, which, as mentioned above, consisted of steel cables straining through tackle on to holdfasts on one bank and balance weights on the other, were replaced by more permanent inclined land ties or back stays. Both are shown in *Fig.* 9, and the substitution in operation in *Fig.* 10.

The nature of these semi-permanent ties can be gauged from the two illustrations just cited. It will doubtless surprise many to find long medium-size reinforcing bars serving the purpose. These are closely grouped, unprotected except at the junctions where closely-bound concrete covers the splices, some of which occur in mid-air.

The south stay is anchored to a buried holdfast through steel links, as shown in *Fig.* 9, but the north stay, the end of which is seen in *Fig.* 10 and also in the finished state in *Fig.* 11, is attached through pin joints to counterweights

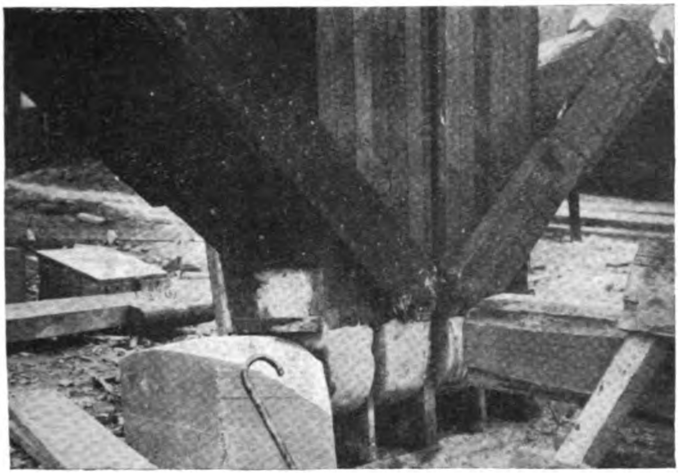


Fig. 7.—Pin-joint at Foot of Mast.

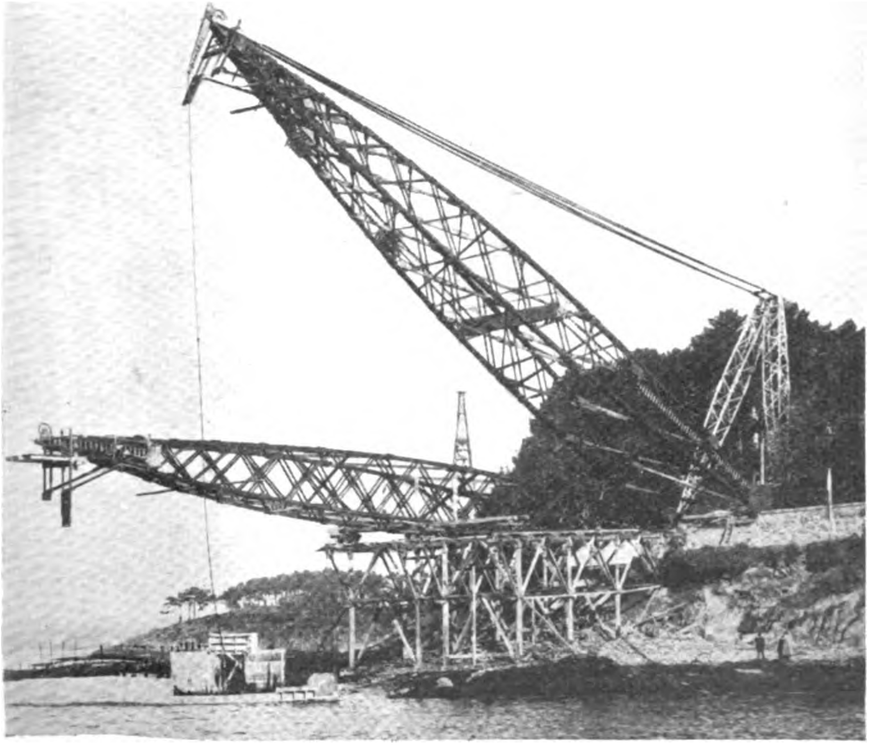


Fig. 8.—Masts being Hoisted.

sliding on rollers on the inclined rails supported by the concrete buttresses in the foreground. Thus all joints and connections capable of movement, both of the cable and the masts, are pinned so that temperature and operation stresses do not set up secondary strains.

Each of the bearing cables has a clear span of about 2,230 ft. and carries an operating cabin and gear weighing 4,000 lbs. for transporting a normal charge of 2 tons or an occasional load up to 4 tons. The ultimate strength of each cable is 200 tons which, with a factor of safety of 3·5, allows about 57 tons as the working pull on each cable. In addition, they are insulated and charged positively. The carriage and gear are, of course, earthed and a lower but smaller diameter cable serves as the earthed return for the power required in operation. A view of the carriage is given in *Fig.* 19.

Concrete and Stresses

Referring now to the permanent work, it will probably be desirable to include a note on the mixture of the concrete with the description of the members themselves. Nevertheless, the following remarks give a general idea of the procedure and summarise the figures.

The concrete is usually mixed fairly wet, and after placing is vibrated. It is contended that this eliminates any excess water while rendering the concrete easily workable.

Permanent work at or below sea-level is executed with aluminous cement. The remainder is of ordinary Portland cement from the Boulonnais district or equivalent.

Generally speaking the mixtures of concrete employed are approximately as under. The second row of figures in square brackets gives the equivalent volumetric proportions.

For *Foundations.*—

Stone.	Fine Stone and Dust.	Natural Sand.	Aluminous Cement.
700	250	250 Litres	400 Kgs.
[1·75	·63	·63	1·0]

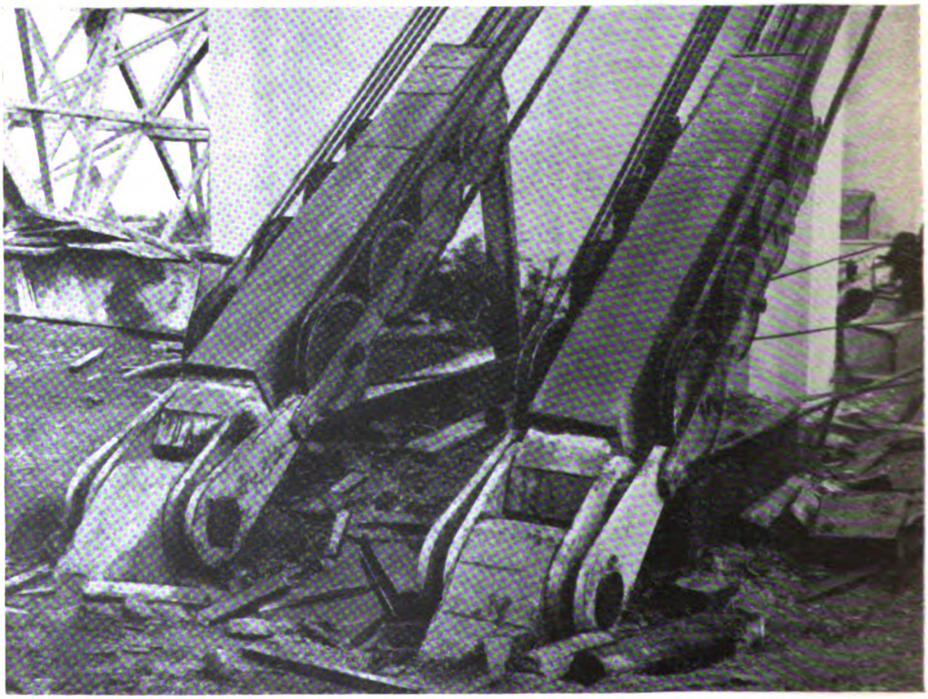


Fig. 9.—Anchorage of South Stay.

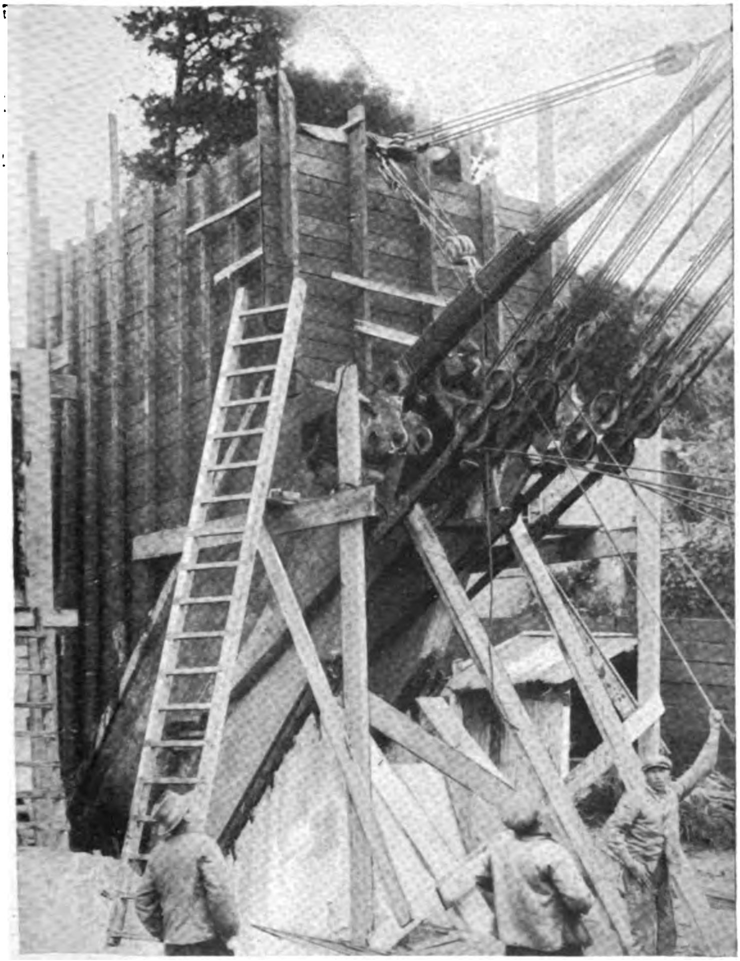


Fig. 10.—North Stay: Replacing Temporary Hauling Tackle by Backstay and Links to Counterweight.

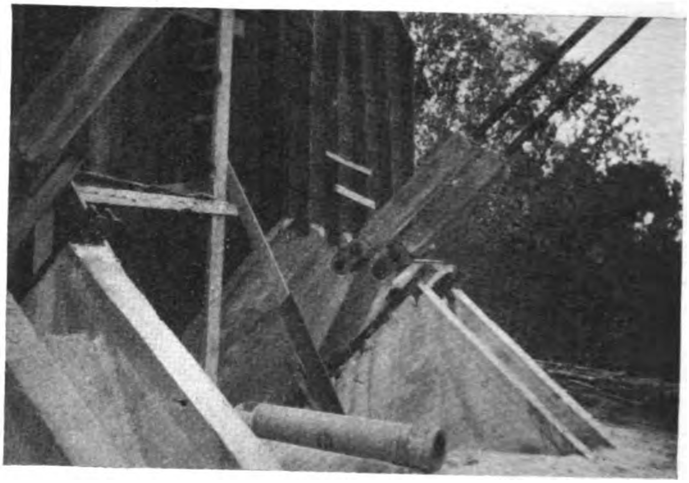


Fig. 11.—Completed North Stay and Ballasted Counterweight.

For *Decking, piers of viaducts, and work above arches.*—

Stone.	Fine Stone and Dust.	Natural Sand.	Portland Cement.
700	250	250 Litres	350 Kg.
[2·86	1·0	1·0	1·0]

Minimum ultimate stress at 90 days = 3,400 lbs. per sq. in. Maximum working stress = 850 lbs. per sq. in.

For *Arch ribs.*—

Stone.	Fine Stone and Dust.	Natural Sand.	Portland Cement.
800	200	200 Litres	400 Kg.
[2·85	·7	·7	1·0]

Minimum ultimate stress at 90 days = 4,250 lbs. per sq. in. Maximum working stress = 1,060 lbs. per sq. in.

The reinforcement consists of plain round mild steel bars.

High Tension Reinforcement.

We have received the following communication from Mr. Hugh H. Burness, B.Sc., A.M.Inst.C.E., A.M.I.Mech.E., of the Technical College, Bradford.

Sir,—Mr. E. S. Andrews, in his article on "High Tension Reinforcement" in your November number, shows that for a given beam or slab the amount of steel can be considerably reduced by the use of steel having an allowable working stress of 20,000 lbs. per square inch. A point that is usually lost sight of in this connection is that, using the generally accepted formulæ for design, the smaller quantity of high tensile steel requires a greater quantity of concrete for economical working, i.e. for the simultaneous development of the assumed stresses in concrete and steel. Consequently the saving in steel may be outweighed by the additional cost of concrete even if the steel prices are the same, while the balance is altogether in favour of mild steel when the higher price of medium carbon steel is taken into account.

The following analysis may be of interest to some of your readers:

For rectangular beams or slabs reinforced on the tension side only the following formulæ apply:

$$(1)\quad \frac{\text{Depth to neutral axis}}{\text{Effective depth of beam}} = \frac{y}{d} = n = \frac{mc}{f + mc}$$

$$(2)\quad \frac{\text{Area of steel}}{\text{Area of concrete}} = p = \frac{nc}{2f};\ m = \frac{E_s}{E_c} = 15 \text{ (say)}$$

$$(3)\quad \text{Moment of Resistance of beam} = \frac{cn}{2}\left(1 - \frac{n}{3}\right)bd^2$$

$$M = kbd^2.$$

When $c = 600$ $f = 16{,}000$ $m = 15$, these have the well-known values

$$n = 0\cdot36 = \frac{9}{25};\ p = 0\cdot00675\ \ M = 95bd^2$$

When $c = 600$ $f = 20{,}000$ $m = 15$, the values are

$$n = 0\cdot31 = \frac{9}{29};\ p = 0\cdot00465;\ M = 83\cdot4bd^2.$$

If we assume a constant ratio of b to d for beams for equal strength the ratio of cross-sectional areas will be $\left(\frac{95}{83\cdot4}\right)^{\frac{2}{3}} = 1\cdot09$, i.e. the beam with high tensile steel has 9 per cent. more concrete.

The steel areas are in the ratio $\frac{0\cdot465}{0\cdot675} \times 1\cdot09 = 0\cdot754$, i.e. the saving in weight of steel is 25 per cent.

It remains to calculate the relative costs of the two beams. Assuming the price of concrete at 2*s*. per cubic foot, mild steel at 12*s*. per cwt. = 52*s*. 6*d*. per cubic foot, and medium carbon steel at 20*s*. per cwt. = 87*s*. 6*d*. per cubic foot.

For two beams of equal strength that with mild steel reinforcement being 1 square foot in cross-sectional area the cost per foot run is

		shillings.
(1)	1 cubic foot concrete @ 2*s.*	= 2·0
	0·00675 cubic foot steel @ 52*s.* 6*d.*	= 0·354
	Total	= 2·354

		shillings.
(2)	1·09 cubic foot concrete @ 2*s.*	= 2·18
	·00465 × 1·09 cubic foot steel @ 87*s.* 6*d.*	= 0·444
	Total	= 2·624

This shows a saving of 12 per cent. in favour of the mild steel.

The actual difference in cost will, of course, vary in various designs, but it would apparently be greater if a percentage of steel higher than the economic were used, as is often the case; while the most favourable case for high tensile steel would occur in **T**-beams where the increase in concrete might be negligible.

If we consider the effect of raising the allowable stress in the concrete by 25 per cent., i.e. to 750 lbs. per square inch, we get

$$n = \cdot 413,\ p = \cdot 0097,\ M = 134bd^2$$

and costs as before; the cost per foot run of a beam 1 square foot cross-sectional area using $c = 600, f = 16{,}000$ is again 2·354 shillings; using $c = 750, f = 16{,}000$ for a beam of equal strength, the cost is 2·007 shillings per foot run, showing a saving of 14½ per cent.

Our endeavours should then be towards raising the allowable working stress in the concrete by the selection and use of the best possible aggregates, and ensuring proper grading and consistency on the job. Modern British Portland cement used in ordinary proportions will allow of much higher working stresses than 600 lbs. per square inch if suitable aggregates can be obtained.

The Institution of Structural Engineers.

To fill the vacancy caused by the death of Sir Charles Ruthen, the Council of the Institution of Structural Engineers has appointed as President Mr. H. J. Deane. To fill the vacancy for a Vice-President caused by Mr. Deane's elevation, the Council has appointed Mr. Ewart S. Andrews.

Brooklands Track.—Mr. A. G. Stedman, M.S.E., M.I.Struct.E., of 317, High Holborn, W.C.1, has been appointed consulting engineer (civil) for Brooklands Track.

Formwork.

When we published in this journal a few of the chapters from the treatise by Mr. A. E. Wynn, B.Sc., A.M.Am.Soc.C.E., on "The Design and Construction of Formwork for Concrete Structures," we had so many requests to publish them in book form that our readers will be glad to know that this has been done and that the volume is now ready. A small part of the work only appeared in this journal. In the book now published designs and notes on formwork for every type of concrete structure are given. An idea of the comprehensive nature of the work may be gained from the following list of chapters.

Chapter I.—Form Building in General.
Chapter II.—Materials, Loads, Pressures and Stresses.
Chapter III.—Theoretical Design of Forms.
Chapter IV.—Design Tables.
Chapter V.—Design Problems.
Chapter VI.—Detail Construction of Footing Forms.
Chapter VII.—Detail Construction of Column Forms.
Chapter VIII.—Wall Forms.
Chapter IX.—Detail Construction of Beam and Girder Floor Forms.
Chapter X.—Forms for Rib Floors and Structural Steel Fireproofing.
Chapter XI.—Miscellaneous Forms in Building Construction.
Chapter XII.—Forms for Flat Slab Construction.
Chapter XIII.—Forms for Conduits, Sewers and Culverts.
Chapter XIV—Forms for Tanks, Silos, Bins and Standpipes.
Chapter XV.—Forms for Dams, Piers and Heavy Walls.
Chapter XVI.—Steel Forms in Building and Wall Construction.
Chapter XVII.—Steel Forms for Curved Surfaces.
Chapter XVIII.—Arch Falsework.
Chapter XIX.—Other Bridge Forms.
Chapter XX.—Patent Devices.
Chapter XXI.—Planning the Work.

Wood shuttering for every purpose in building construction and engineering works is dealt with, and in each case are given clear drawings showing the best method of construction, details of costs, quantities of materials required, and full explanatory notes on preparing and erecting the formwork. Steel forms are fully dealt with in two chapters, while the many devices which are common practice in the United States but practically unheard of in this country are described and illustrated.

A special feature of the volume are the design tables, from which the most economic selection of materials for different purposes may be seen at a glance. These tables, which are presented in a large and clear style as folders, include:

1. Maximum span of floor sheathing for various thicknesses of slab.
2. Maximum span of wall sheathing for various heights of wall.
3. Maximum span of column sheathing for various heights of column.
4. Maximum spacing of floor joists for various spans and thicknesses of slab.
5. Maximum concentrated loads carried by ledgers and wales for various spans and spacing of loads.

6–9. Spacing of column yokes for various sizes and heights of column.

10. Maximum spacing of wales and wall ties of various sizes of studs and heights of wall.
11. Safe loads on posts.

There are no less than 219 illustrations (diagrams and photographs) covering formwork for every type of structure, all reproduced on a large scale.

This is the only book in the English language dealing exhaustively with shuttering for concrete structures. The author, who is a practical designer and contractor, has had a very wide experience in all classes of construction both in this country and America, and has made a special study of the subject of formwork. The results of his experience are given in this volume in simple language, so that advantage can be taken of it by all concerned with the erection of concrete structures.

The book is strongly bound in cloth, and comprises 320 pp. It is obtainable from Concrete Publications, Ltd., 20 Dartmouth Street, Westminster, S.W.1. Price 20*s*. (postage 9*d*. extra).

Questions and Answers relating to Reinforced Concrete.

***Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.*—Ed.**

Hollow Tile Floors.

Question.—In the design of a hollow tile floor, can the top of the tile which comes in the compression flange be considered in the strength of the floor, providing there is a suitable factor of safety against crushing of the tile ?

The only reason against considering the top of the tile as part of the compression area seems to be the inevitable open joints between them, caused through (1) ends not being true, (2) walking on by concreters, (3) falling out of mortar when jointed by shortness and disturbance when concreting.

Is it safe to assume that the concrete fills these joints sufficiently to transmit the compression from one to the other, or that the adhesion between the side of the tile and the rib is sufficient to bridge the joint ?

J. D.

Answer.—In general it is not safe to assume that these joints are sufficiently filled to transmit the compression. Having regard to the fact that the top of the tile is in any case so near the neutral axis that the stress in the material would be of much less value than that in the concrete above it, the advantage of taking it into account would seldom exceed the equivalent of ¼ in. additional thickness of concrete, which is undoubtedly better construction. There is no doubt that the existence of the tile does add somewhat to the strength, if only by reason of reducing the length of the short strut between one tile and another, and concrete will stand a higher stress on a short compression specimen than it will on a long one. Over the actual tile the concrete is of course supported by it, and does undoubtedly receive some benefit from its existence. It is difficult to say exactly how much value the tiles have by reason of these two rather complicated considerations, and a structure which is intended to have a really adequate margin of safety would be best designed independently of any assistance from the tile.—O. F.

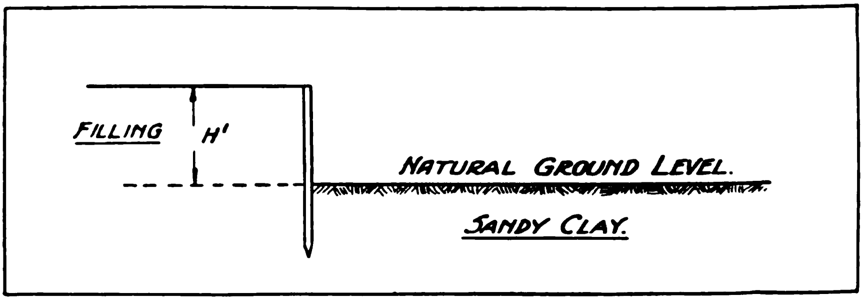
Sheet Piling.

Question.—I should be grateful if you would indicate a method for determining the depth to which sheet piles should be driven in the general case shown in the diagram below.

R. L. M. Dick.

Surbiton.

Answer.—The problem referred to is one which is generally solved in a different way, i.e. by the use of king piles tied back into the filling with a beam running along the top of the king piles supporting the sheet piles at the top. It is seldom that the depth of filling is small enough to make the use of sheet piles without a tie-back either satisfactory or economical.



(*See Inquiry from R. L. M. Dick.*)

If, however, it is desired to work on the lines suggested in the question, the method to be adopted would be to draw at the back of the sheet piles a pressure diagram giving the outward pressure against the piles (which might be in accordance with the formula 40 h), and to draw on the outside piles a diagram of pressure which the soil on the outside will stand without lifting (which might be in accordance with the formula $p = 360\,h$) and then find a depth of pile which gives the bending moments of these two pressure diagrams above the point of the pile equal. It would, however, be advisable to drive the piles somewhat farther than this so as to secure a factor of safety, as the previous solution would be one at which the forces over were just balanced.—O. F.

Correspondence.

PROPOSED CONCRETE PRODUCTS' ASSOCIATION.

SIR,—In view of the continued growth of the concrete products' and cast stone industry in this country, the British Portland Cement Association Limited has frequently been asked to promote the formation of a body similar to the Concrete Products' Association of America, which has done such valuable work on behalf of the cast stone and concrete products manufacturers in that country.

The objects of such an Association would be to help the industry in every way possible, including:

> The provision of opportunities for those engaged in the industry to meet and discuss their difficulties, and to get to know one another;
>
> To provide its members with early information regarding new processes and materials that will be of value in reducing costs and improving quality;
>
> The formation of a body which, by speaking for the whole industry with a united voice, would have considerable influence with local authorities and others specifying concrete products;
>
> To take up with the railway companies the question of freights on concrete goods;
>
> To build up co-operative propaganda to promote the sales of concrete articles;
>
> To educate the public in the uses of concrete;
>
> Generally to work on behalf of the industry in all the multifarious directions in which other industries have found such an association invaluable.

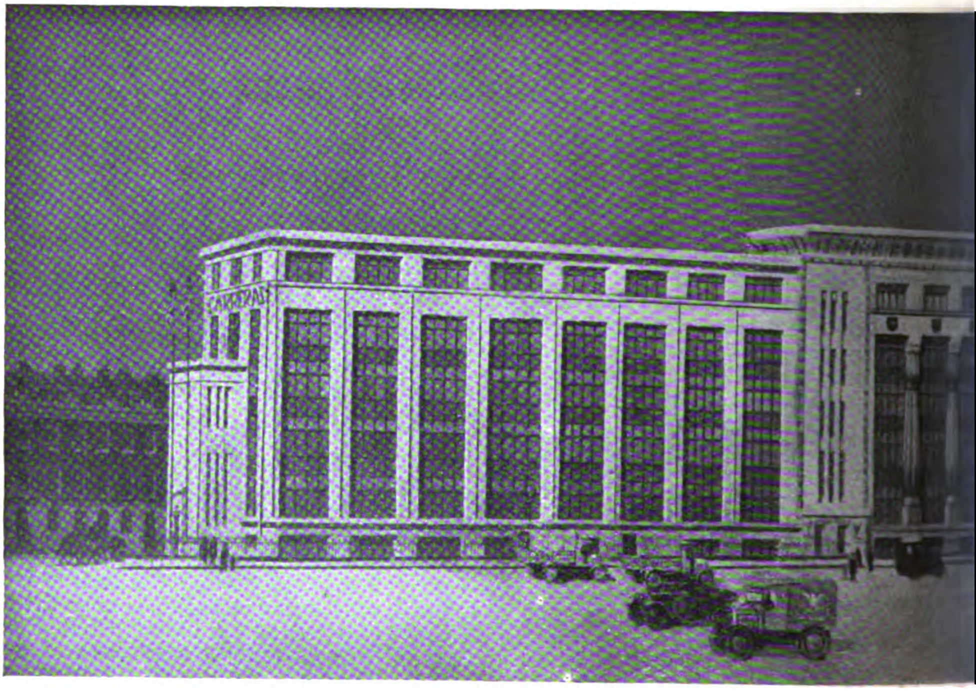
In America the Concrete Products' Association has proved its value to the full. It has improved the quality of concrete products by disseminating knowledge amongst its members. It has promoted sales until they reach dimensions undreamt of in this country—official figures show that last year alone no fewer than 500,000,000 concrete articles of all descriptions were made and sold in that country.

It would be the object of the proposed British Concrete Products' Association to perform the same services for the industry in this country. Already many manufacturers have signified their approval of the proposal and have asked to become members if the Association is formed, and these firms include not only the leading concerns in the industry but also many firms in quite a small way of business. The Association would be entirely self-supporting; my own Association has merely been requested to assist in its formation.

Everyone making cast stone or concrete products is invited to join. Only by being thoroughly representative will the Association be of most use to the industry. Full particulars of the proposal will be sent on application to the Secretary, The British Portland Cement Association, Limited, 20, Dartmouth Street, Westminster, S.W.1.

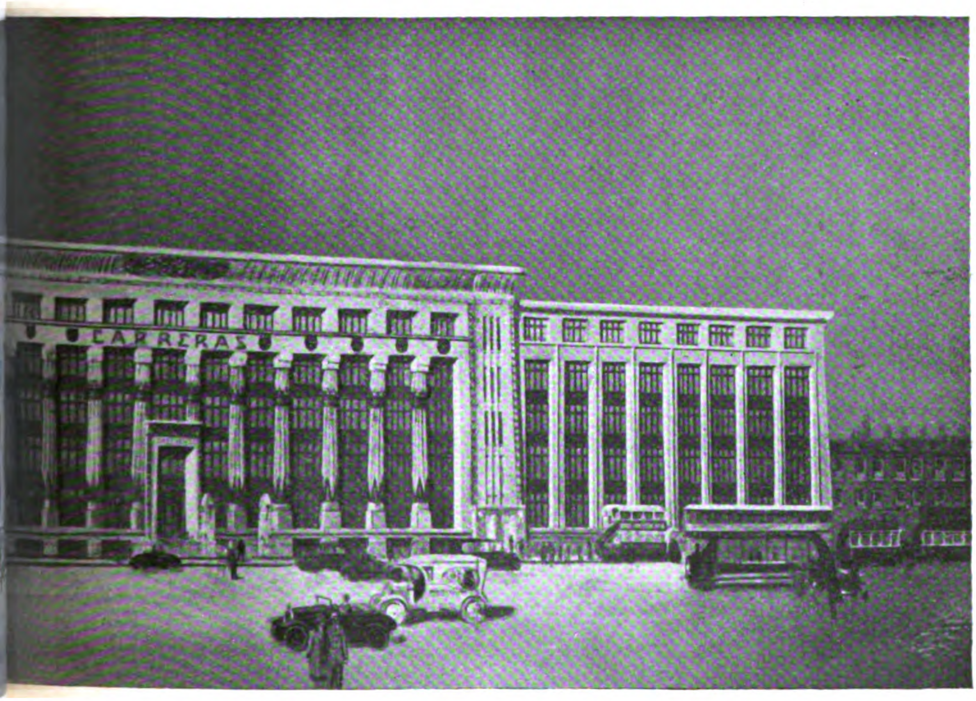
A. C. CRITCHLEY,
Vice-President,
British Portland Cement Association, Limited.

New Building for Messrs. Carreras,



**[Some notes on this important new reinforced concret
concrete with cast stone elevations in colour, at a cost
The reinforced concrete design is by Messrs. Considèr
Robert McAlpine & Sons.]**

Limited, Hampstead Road, London.



[*Architects, Messrs. M. E. & O. H. Collins, in collaboration with Mr. A. G. Porri.*

building, which is to be built entirely of reinforced
of about half a million pounds, are given on page 765.
Constructions, Limited, and the constructors are Sir

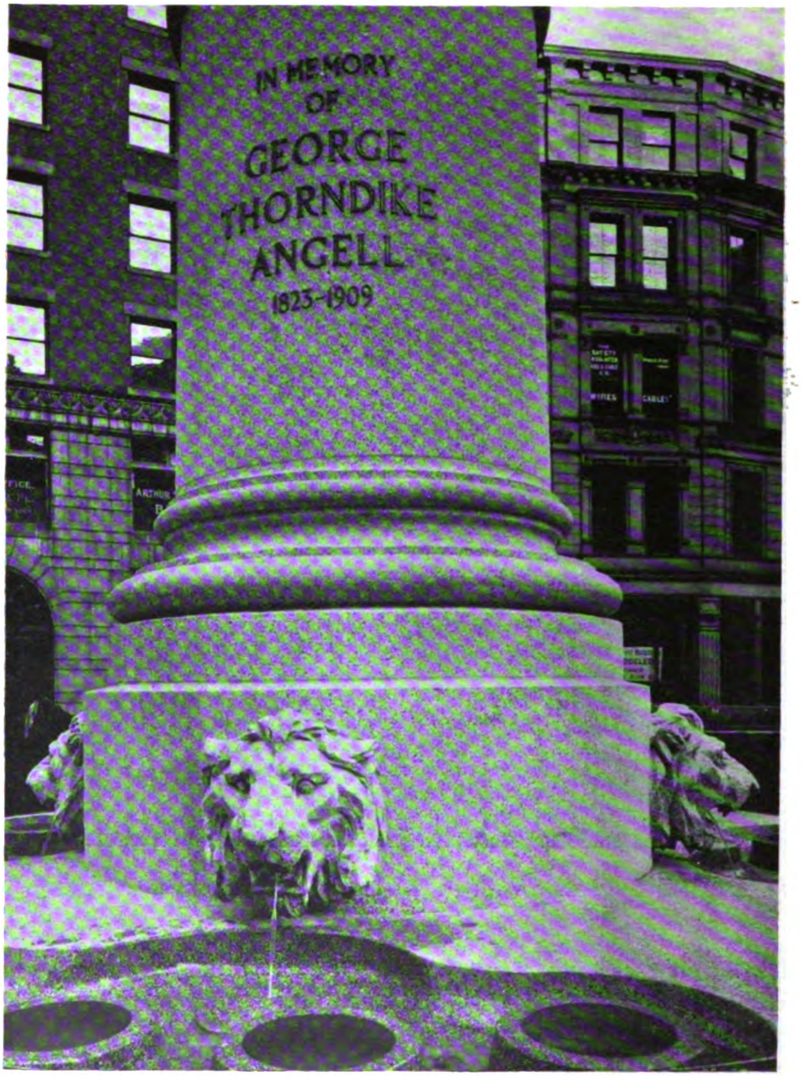


Fig. 2.—Granite-Concrete Fountain: Surface Hand Tooled. A close-up view of one of the Lion's Heads is given on p. 793.

Concrete Surface Treatment.

In this number we are able to illustrate some particularly good examples of surface-treated concrete, in which the effect has been obtained by ordinary masonry tooling processes. *Fig.* 7 is concrete made of crushed Portland stone and tooled to a ribbed finish; *Fig.* 5 shows an aggregate of marble chippings finished to a smooth surface by rubbing; *Fig.* 3 is a mixture of crusted granite chippings with the surface left slightly rough by the chisel; *Fig.* 1 is a lion's head of granite aggregates roughly moulded and then finished by hand. The endless varieties of surface colour and texture of which concrete is possible are strikingly demonstrated by these and the other illustrations of different surfaces.

Selection of aggregate is, of course, the first essential of success; the other processes are simply ordinary concreting and mason's practice. Rubbed finished

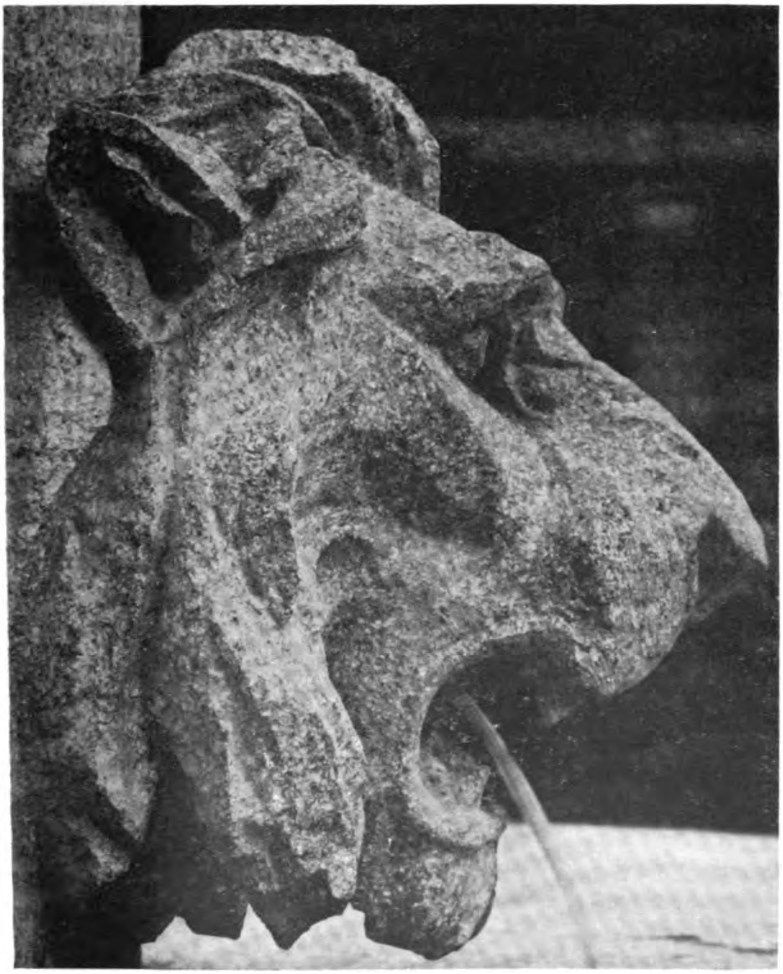


Fig. 1.—Close-up view of Lion's Head, showing how closely cut Granite-Concrete resembles Natural Stone.

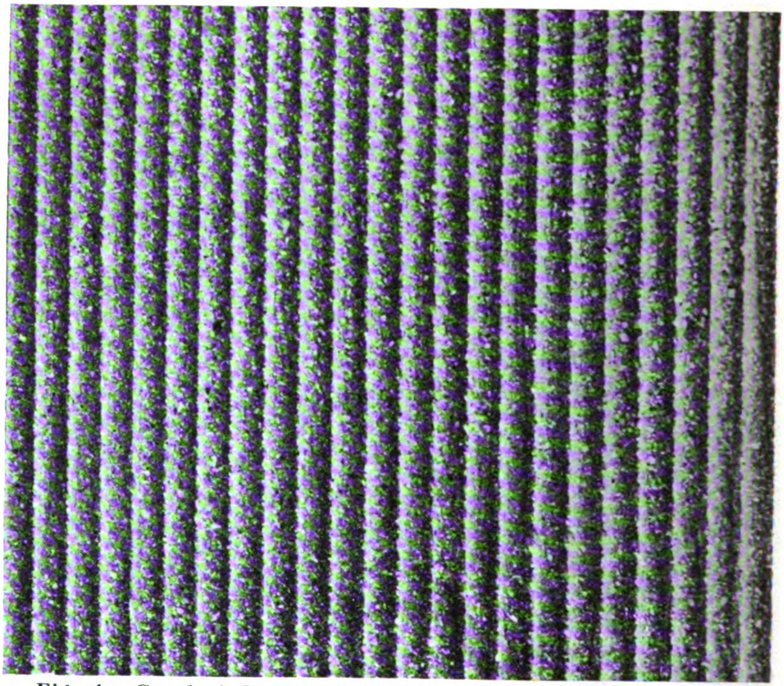


Fig. 4.—Crushed Granite Aggregate Tooled to Ribbed Surface.

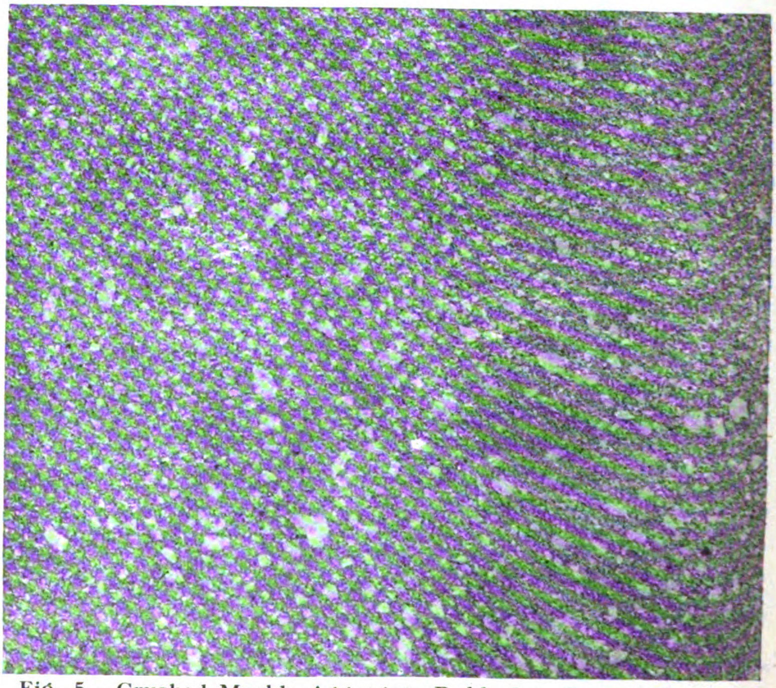


Fig. 5.—Crushed Marble Aggregate Rubbed to Smooth Surface.

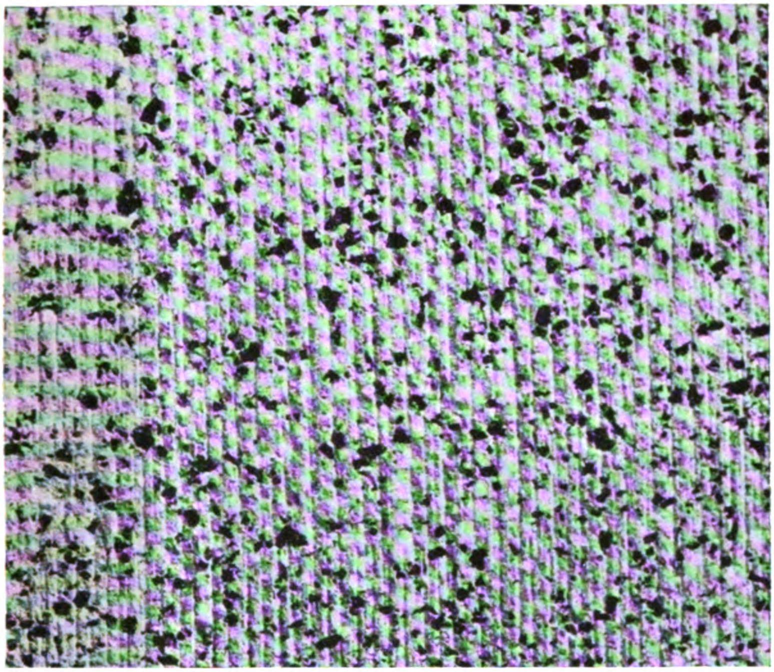


Fig. 3.—Tooled Surface of Stone with Black and White Marble Chipping as Aggregate.

are generally obtained with carborundum stones. It is recommended that the first rub should be completed as soon as the forms can be removed; faces and sides of columns should be stripped in 24 hours if possible, and the soffits of beams should be treated within three or four days. As soon as the forms are removed the surface should be thoroughly wetted and then rubbed with carborundum stone. The rubbing will remove board marks, nailhead marks, and to a certain extent the irregularities between boards.

The cement paste which works up in the rubbing process should be removed by washing and brushing. Small voids in the concrete should be filled with a mortar (usually 1 : 2) composed of finely-screened aggregate of the same general description as that used in the concrete. This mortar should be worked into the face with the carborundum stone and left even and regular.

The best and most economical results are obtained by applying the first rub to the concrete while it is green. Filling the small voids with mortar offers no difficulties, but the operator should be warned against leaving an appreciable thickness of mortar on the face of the concrete to take up irregularities in the surface, unless special precautions are taken to ensure the bond. Such precautions are particularly necessary when the surfacing is delayed until the concrete has hardened and dried out.

If the concrete cannot be given the first rub when it is still green, board marks, nailhead marks, and small projections must first be removed. After thorough wetting, the surface should be coated with a cement wash in order to help the grinding action. The carborundum rub should then be given, taking care to remove all the cement wash by washing and brushing.

The second rub should be applied near the end of the work, when the building is ready to clean down and danger of staining from other work is past. The surface should be thoroughly wetted, and then gone over with a carborundum stone. The paste which is worked up should be removed with a wet brush, and when dry the finished surface will resemble limestone in colour and texture.

The Process outlined above is an inexpensive method of improving the appearance of large wall surfaces. The result shown in *Fig.* 4 is, of course, obtained by the use of specially selected aggregate and continuing the rubbing process until the surface is as smooth as polished marble; this can be done by hand or by the usual machines used for polishing marble.

The best results are obtained when the same stone is used throughout the surface to be treated. In the case of weak natural stones it is often possible to use them in building when without being reconstructed and strengthened by the cement it would be impossible to use them at all, for the process of crushing and binding greatly adds to the crushing strength of most natural stones.

The first essential is to select a suitable aggregate, and of these there is the whole range of natural stones to choose from. Besides pit sands, gravel, and flint, such materials as marble chippings in different colours and any kind of suitable crushed stone, broken brick, etc., may be used for purposes where they are suitable.

The point to be borne in mind is that the aggregate will not be completely hidden as in ordinary concrete work, but that the surface will, in fact, after treatment, have exactly the same appearance as the material of which the concrete

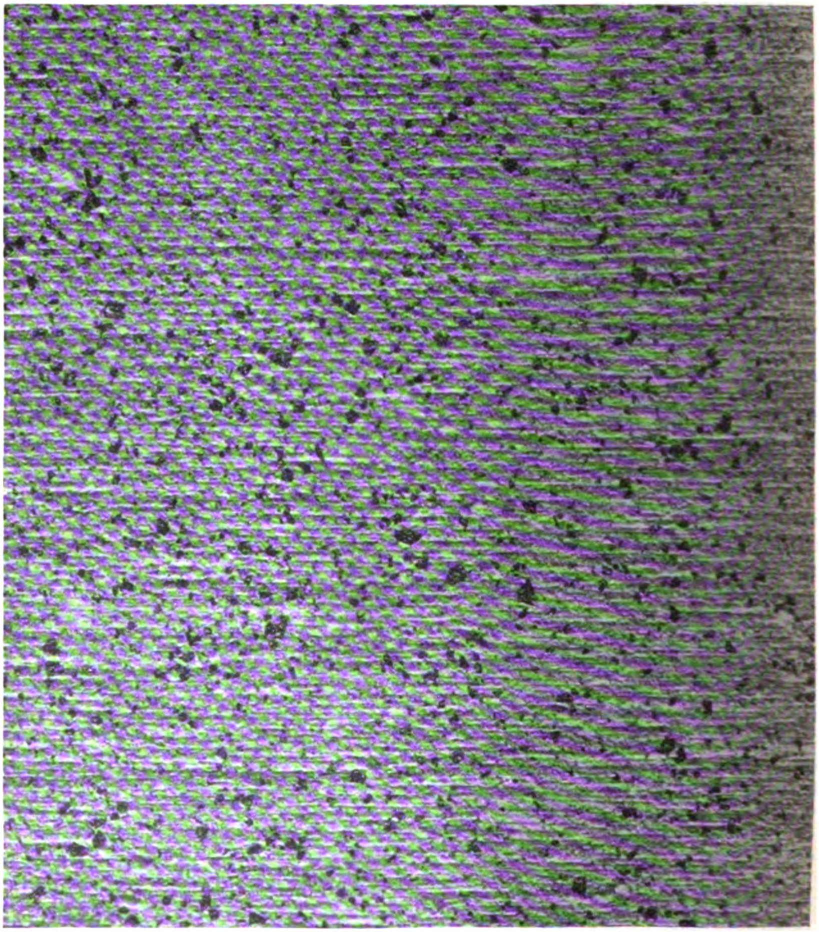


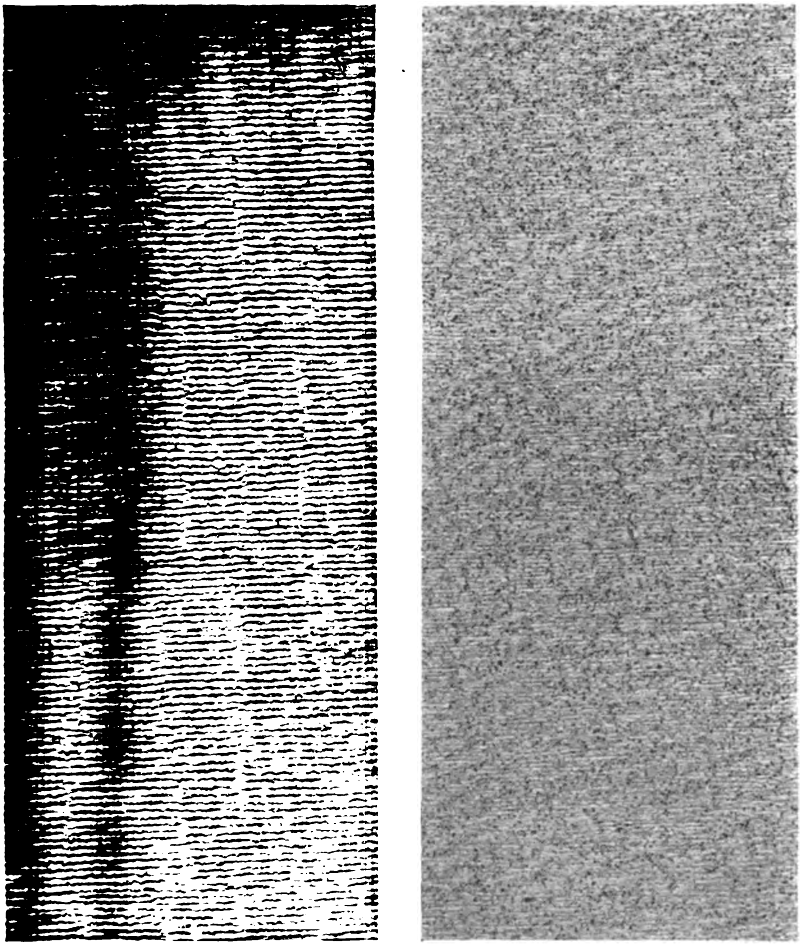
Fig. 6.—Granite-Concrete with Tooled Face left slightly rough.

is made as though the cement were not present at all. The result will be reconstructed stone. If Portland stone be used, the product will resemble that stone. If broken red brick be used and the material moulded to the shape of a brick, the product has every attribute of an ordinary red brick so far as colour is concerned.

As it is desirable that little or none of the cement should show the material should be as well graded as possible, and thorough grading is an additional advantage in preventing the formation of small pockets when the cement is tooled from the surface. The cement should also be coloured if necessary to the colour of the aggregate, or white cement used for lighter shades.

Except for high-class cast-stone work for important buildings, it is usual to use these special aggregates for the face only, using ordinary ballast concrete for the backing. If, as is usually the case, the stone for the surfacing is crushed to pass a ¼-in. ring the topping need not be more than ½ in. thick.

If a coloured facing only is desired by this process, in the case of pre-cast articles the facing is formed by placing a layer of from ½ in. to 1 in. of the special crushed stone and cement at the bottom of the mould and then pouring the backing of ordinary concrete. When the articles



Figs. 7 and 8.—Textures obtained with different Tools.

are made face up, the backing is first poured and tamped to within ½ in. or 1 in. of the top of the mould and the facing then poured and screeded off level.

Whichever method is used care must be taken to ensure that the second concrete is poured before the first has set, in order to secure a thorough bond. In the face-up method it is advisable to roughen the top of the backing before placing the face so as to give a good key. If there is any considerable interval between the pouring of the two concretes, that poured first should be coated with a wash of neat cement to ensure good adhesion.

In walls built *in situ*, a thin shutter (usually a well-oiled metal plate) is placed between the outer forms to keep the special concrete from the backing while it is being poured. Distance pieces are fixed at the top of the plates to keep them in the desired position within the outer shutters. These plates must be lifted as soon as the concrete has been poured and tamped, in order that the two mixes may come into contact at the earliest moment to ensure a thorough bond.

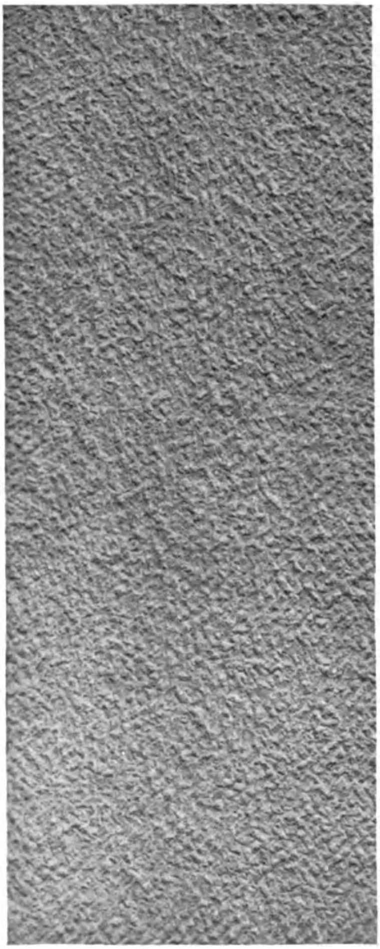


Fig. 9.—Bush-Hammered Face.

After the concrete is poured the special aggregate, whatever its composition or colour, is hidden by the film of cement that comes to the surface of all concrete work, and this has to be removed in order to show the reconstructed stone.

If the surface is to be worked by a mason in exactly the same way as natural stone, and with the same tools, it is, of course, essential that the article should be made with fine material only; otherwise large pieces would be dislodged by the chisel and leave unsightly holes or pitting. For the same reason the concrete must be dense, and thoroughly hardened before it is worked.

In addition to ordinary mason's tools, bush hammers are frequently used for roughening the surface, but this method is hardly ever used for pre-cast articles in which the same effect can be obtained more easily and cheaply. Bush hammering is chiefly used for the treatment of walls poured between shuttering which cannot be removed until the concrete has set.

Fig. 10 is an example of surface treatment by the removal of the cement film by scrubbing with water or acid. The removal of the mortar film by brushing is best performed after the concrete has set but while it is still green, and to this end the forms must be removed as soon as may be done without injury to the structure. How soon this may be will depend upon the character of the structure, the consistency of the mixture, and the weather. No definite rule can be laid down, but in cold weather it is necessary to keep the forms in position much longer than in hot weather.

An ordinary scrubbing brush or a wire brush used with a liberal application of clean water will generally serve the purpose if the concrete is not too hard, but if it is found that the colour of the aggregate is not fully brought out by this treatment a solution of hydrochloric acid diluted with three or four parts of water

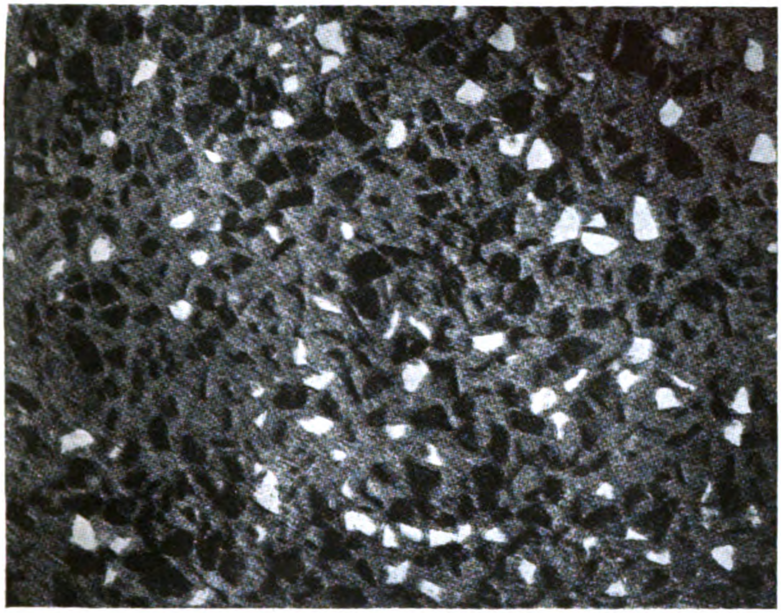


Fig. 10.—Aggregate exposed by Scrubbing.

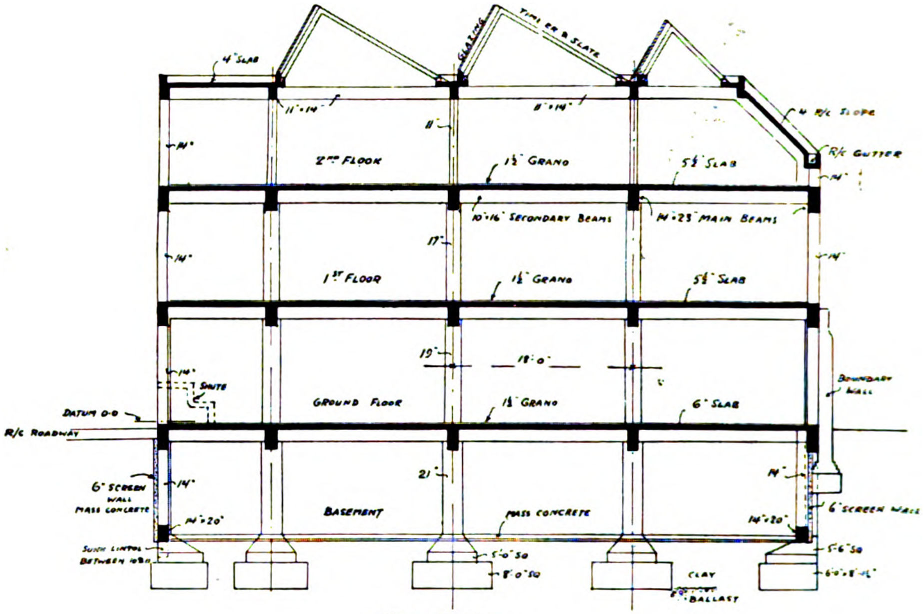
may be employed. Where this is done care must be taken that every trace of the acid is immediately removed from the surface of the concrete by well washing with clean water, preferably by means of a hose. By this method the aggregate is brought into semi-relief and its colour fully revealed.

Reinforced Concrete Warehouse.

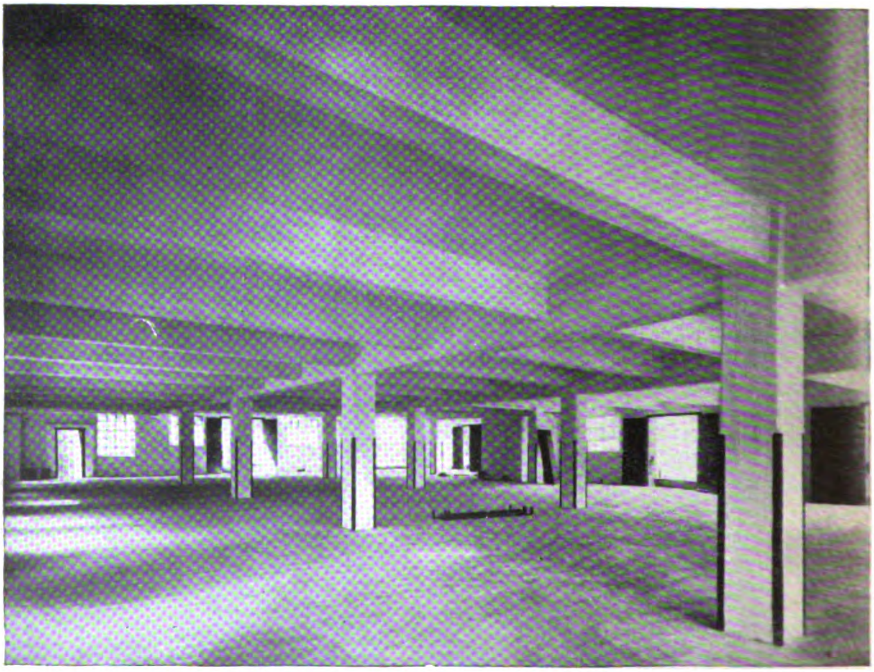
A WAREHOUSE in which the entire framework has been executed in reinforced concrete has been finished recently for Messrs. Leach & Co., at Potters Fields, Bermondsey. As it represents a typical example of heavy warehouse construction, the superimposed load being 3 cwts. per sq. ft., some illustrations are given of the work on pp. 799, 800 and 801.

The general lay-out will be seen from *Figs.* 2, 3 and 4, which show the plan, the cross section, and the longitudinal section of the building, and an interior view is shown in *Fig.* 1.

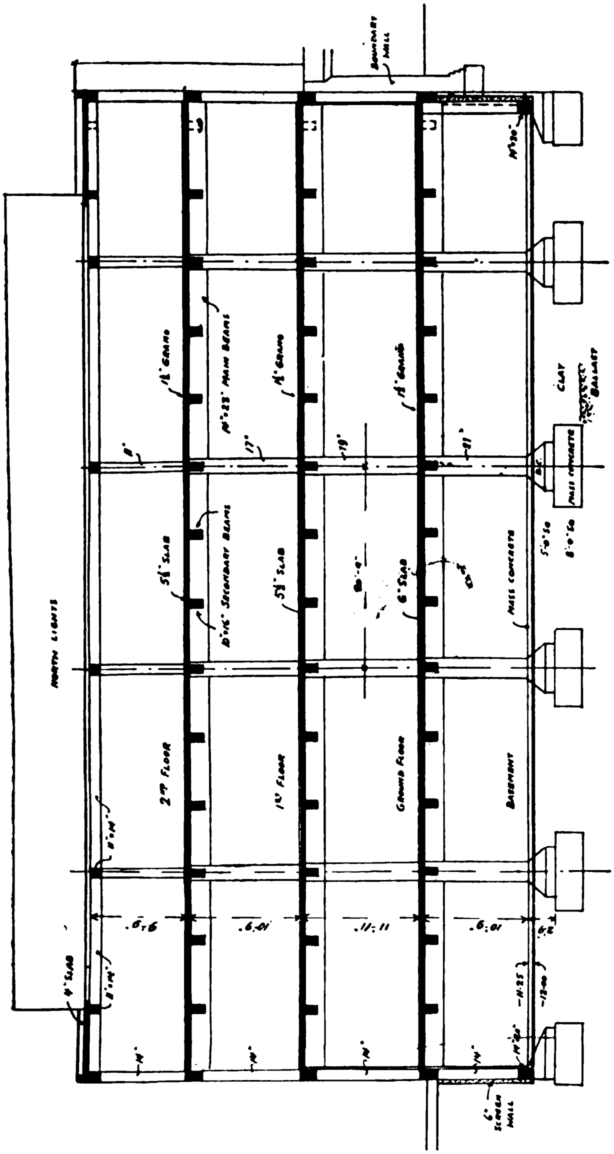
The work was executed by Mr. A. E. Frost, of Wood Green, the architects being Messrs. Stock, Page & Stock, St. Thomas' Street, S.E., and the engineer Mr. R. N. Stroyer, M.I.M.E., Abbey House, Westminster, S.W.1.



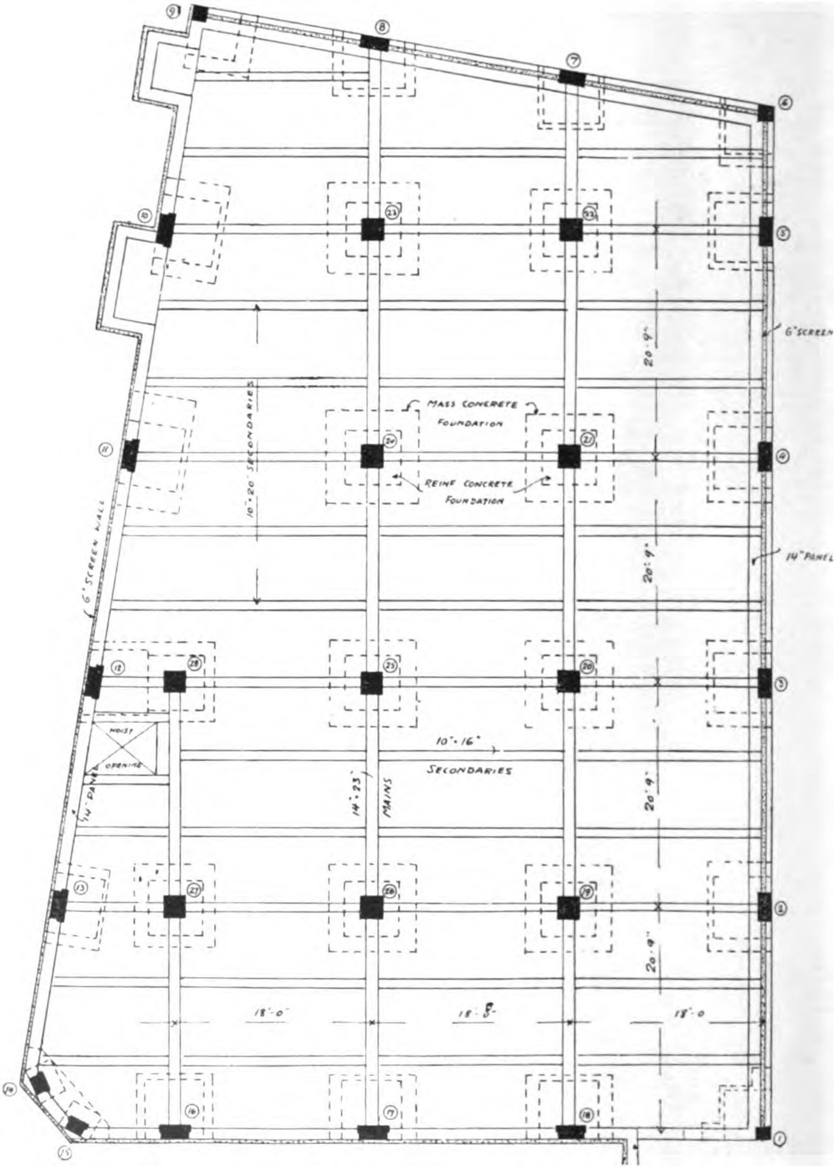
Cross Section.



Reinforced Concrete Warehouse at Bermondsey. (*See p.* 799.)



Reinforced Concrete Warehouse at Bermondsey : Longitudinal Section. (*See p.* 799.)



Reinforced Concrete Warehouse at Bermondsey: Plan. *(See p. 799.)*

New Civil Air Station at Croydon.

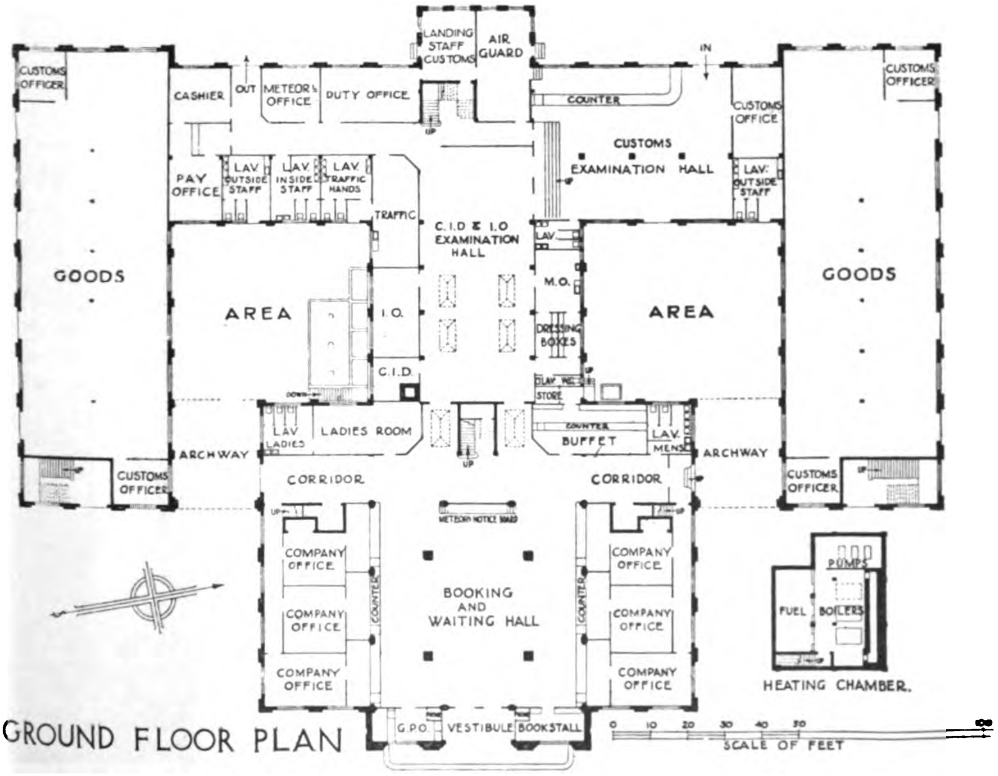
A NEW air station is now in course of construction at Waddon, near the present starting point of the Continental air services at Croydon. An extensive area of land has been acquired by the Air Ministry, who are laying it out with a view to providing a station from which departures and arrivals will take place with the same facility as in the case of railway travel.

The main station building will have a frontage of 250 ft., a depth of 180 ft., and a height of 30 ft., and through this passengers will pass, both for departure for and arrival from an air flight. The main passenger entrance will open on to a large waiting hall, on each side of which will be the booking offices of the different Companies running services. From the booking hall departing passengers will pass by an "outward bound" corridor leading on to the main departure and arrival paved platform, or "apron," which will be about 7,000 sq. yds. in extent and on which all departing and arriving machines will pick up or discharge their passengers. Arriving passengers will pass from the paved platform through the "inward bound" corridor and customs to the main waiting hall for their various destinations.

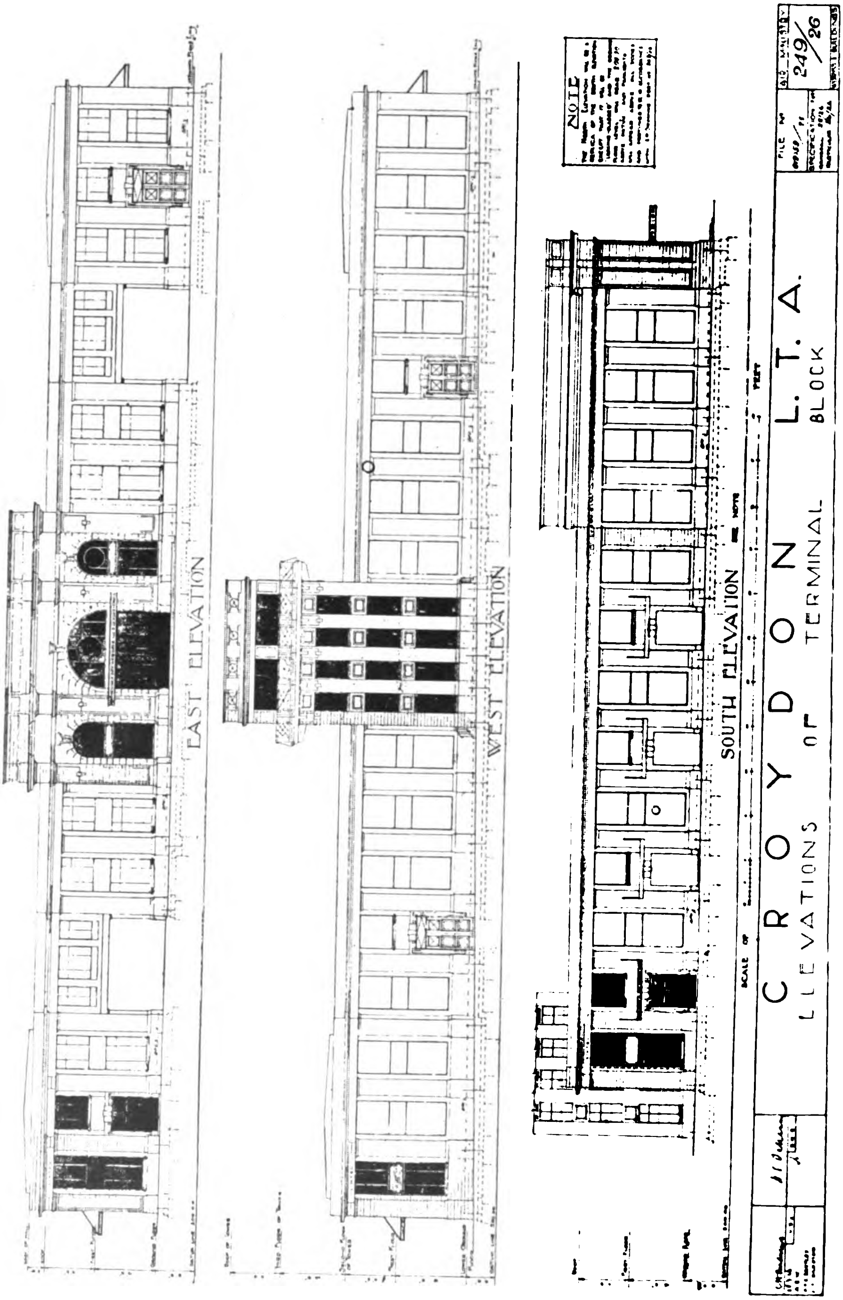
On the ground floor also will be the customs examination hall, buffet, post office, lavatories, etc. The upper floor will be used exclusively for general offices, meteorological and wireless accommodation, etc.

A feature of this building will be the central control tower, 50 ft. high, overlooking the aerodrome and surrounding country, from which communication will be maintained with all pilots arriving and departing.

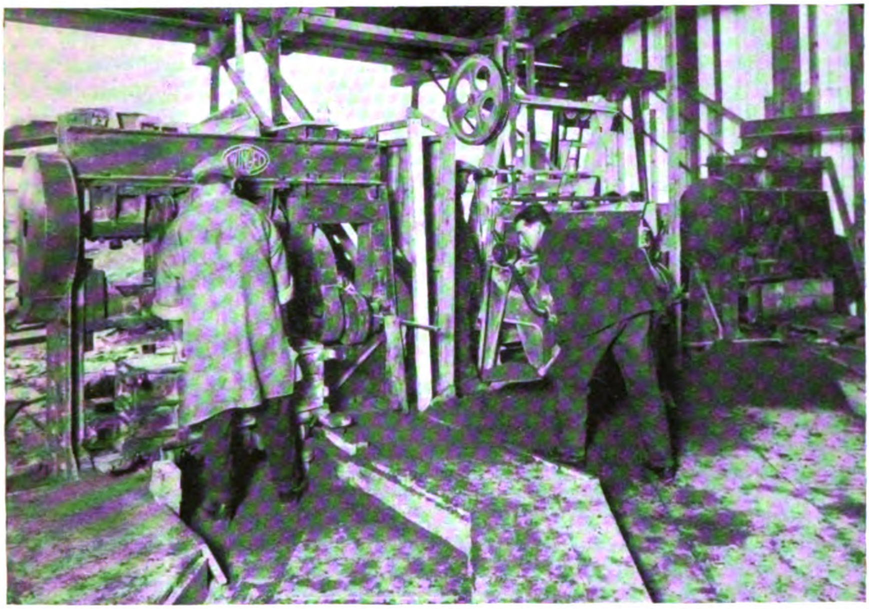
Adjacent to the main station buildings will be two aeroplane sheds each 300 ft. long, 150 ft. wide, by 30 ft. high; each



GROUND FLOOR PLAN



New Civil Air Station at Croydon.



The Slab Making Plant.

shed will have two doors with a clear width of 150 ft., opening on to an extension of the paved platform referred to above. Extensive workshops and storage accommodation will be provided in connection with the aeroplane sheds.

The whole of these buildings will be of steel frame construction, clothed with concrete block walling, in which about 50,000 blocks will be used.

The standard block used measures 3 ft. long by 9 in. high, and varies from 9 in. to 4½ in. in thickness. Many special blocks are being made for corners, reveals, and mouldings. All blocks for external use are faced to a depth of ¾ in. with a special mixture.

For this facing an aggregate of china clay silica sand is used in the proportion of three parts sand to one of rapid hardening Portland cement. This aggregate is practically a waste product of the Cornish china clay industry, obtained when the clay is washed. It is coarse and well graded, very light in colour (nearly white) and contains a proportion of mica which gives a sparkle to the surface. "Ferrocrete" Rapid-hardening cement is used for the whole of the concrete work, but in this facing material the rapid-hardening cement is mixed with 50 per cent. of white cement in order to maintain the light colour of the sand. This mixture gives an excellent face of good texture, the slightly varying shades of each block avoiding monotony in such large wall areas.

A dry mix is used for all blocks and the moulds stripped as soon as they are made. They are then put in the open to cure. About 24 hours after moulding the faces of the blocks are scrubbed with clean water to remove the surface film of cement and expose the aggregate, the exact period varying according to weather conditions. They are then left for a further ten days, during which period they are watered as necessary before being used. This short period between moulding and use is, of course, only made possible by the use of rapid-hardening Portland cement. The special blocks are made by hand in steel-lined wooden moulds to enable their surface to stand the manufacture of a large number of blocks without deterioration, and to give a good face to the concrete. All moulded faces are cast side-face, and rectangular special blocks face down.

The paved platform, or "apron," will be constructed with pre-cast granite-concrete flags 30 in. by 24 in. by 2½ in.

thick, bedded on 1 in. of fine concrete; the slabs are supplied by the Croft Granite, Brick & Concrete Co., Ltd., and Messrs. John Ellis & Son, Ltd., of Leicester. Pre-cast flags have been selected for these "aprons" in order to facilitate repairs.

The floors of the aeroplane sheds will be formed in concrete, divided into 10-ft. squares and finished with a granolithic surface. Siegwart pre-cast beams will be used throughout for the upper floors.

"Winget" plant comprising two power presses ("No. 1 Universal") is used for making all standard blocks throughout the work, with one 4 cu. ft. paddle-arm mixer supplying mixed material, and an additional 3 cu. ft. paddle-mixer for mixing the material for making the special blocks in the wooden moulds. An 18 H.P. "Lister" engine and shafting are used for driving this outfit.

The general contractors are Messrs. Wilson Lovatt and Son, Ltd., of Wolverhampton.

Trass in Concrete.

In a recent issue of the *Journal* of the Institution of Municipal and County Engineers, Mr. Arthur E. Collins, M.Inst.C.E., says:

Any engineer who, like the writer, has recently visited Holland and the Rhine, can hardly have failed to be impressed by the large use of trass by Dutch and German confrères in their marine, river and other engineering works. Trass is no new material. Undoubtedly it was largely employed by the Romans, the strength and durability of whose concrete and mortar are universally recognised. The quarries on the Rhine which the Romans worked are still in being, and the ancient workings in evidence. It is probably from these that Roman supplies for Britain were drawn.

Trass and its uses, however, are too little known to British engineers. The material itself is a volcanic rock (tufa) dried and ground to a fine powder. It contains 58 per cent. silicic acid, 4 per cent. ferric oxide, 15 per cent. aluminium oxide in such condition as in the presence of water to combine with lime into an insoluble hydro-silicate.

To this property is due its great value when used with cement in concrete or mortar. When trass is used with cement the excess of lime becomes a positive advantage, as the trass combines with the free lime and becomes a colloidal jelly, permeating the whole of the concrete or mortar and setting with it into an absolutely impermeable mass, stronger than it would be without such addition. Trass concrete is not affected by sea water, peat ground water, and other actions.

At the same time, it makes concrete or mortar easier to handle, as with similar water content trass concrete or mortar is more plastic, flows more freely into moulds, and is fatter or kindlier to the trowel; this property results in better adhesion to reinforcement. Trass toughens concrete and adds to its elasticity, enabling it to resist temperature stresses and preventing shrinking and cracking whilst maturing. These properties increase the value of concrete for reservoir dams, long retaining walls, road paving, and the like, by making it unnecessary to provide contraction joints, always a source of weakness and cost.

The weight of a cubic yard of cement is about 20 cwt.; that of a cubic yard of trass is 14¼ cwt. In actual practice the volume of trass used often displaces an equal volume of cement, so that at equal costs economy arises. To this saving has to be added that due to the usually lower price of trass, which varies with transport costs.

Boscombe Pier Head Reconstruction and Groynes.

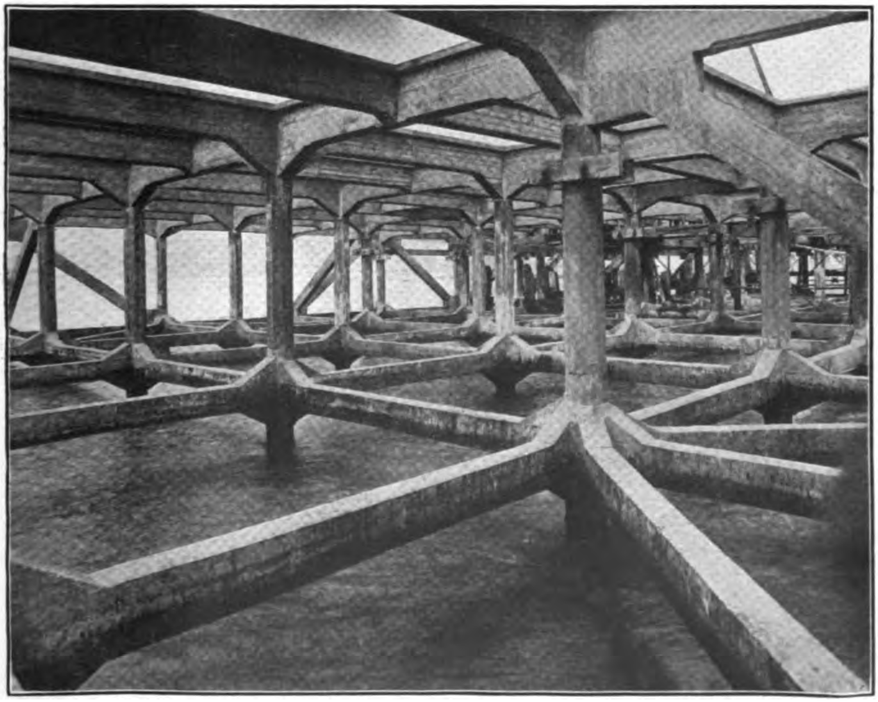
THE Old Iron Pier at Boscombe was built in 1888 for a private company, and purchased by the Bournemouth Corporation in 1903, a bandstand being added a year later. Due to the growing importance of the Boscombe area of the borough of late, the pier was found inadequate, and the Council decided as a first instalment to reconstruct a new and larger head to provide accommodation for music and other entertainment and also refreshment, the old pier neck being retained for the present.

The New Pier Head is built on sixty-two 15 in. by 15 in. octagonal reinforced concrete piles at 18 ft. by 18 ft. centres, giving a pier head of 185 ft. by 90 ft. (against 112 ft. by 38 ft. 6 in.), the end being 73 ft. farther out to sea. The decking is 5 in. by 2½ in. Jarrah on 9 in. by 3 in. Jarrah joists at 3 ft. centres. The concert enclosure is 96 ft. by 50 ft., and there is a 12-ft. 6-in. promenade outside.

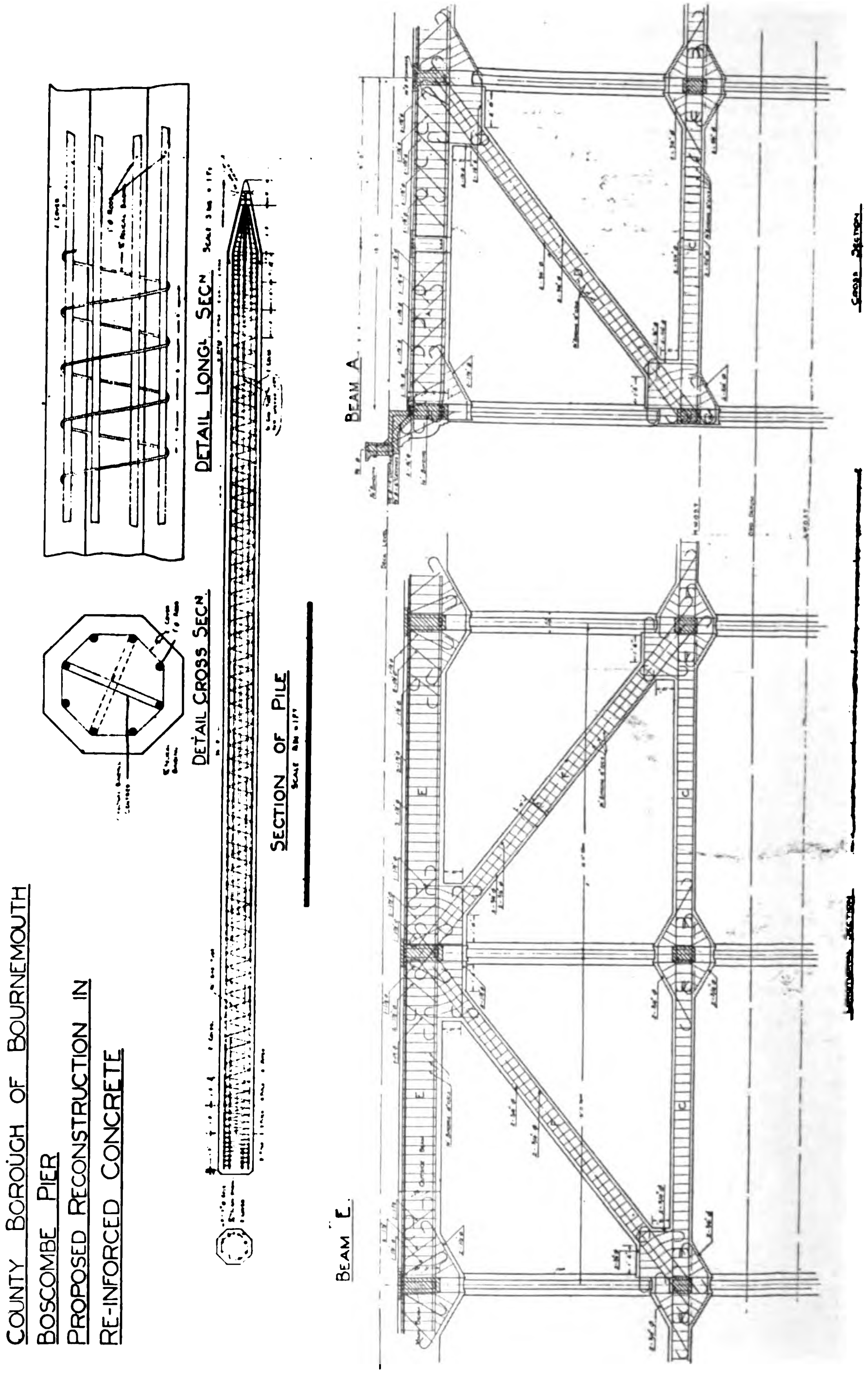
The piles are 51 ft. and 56 ft. long by 15 in. by 15 in. octagonal, reinforced with eight 1-in. rods, 2 in. clear cover, with 5/16-in. spiral binding at an average of 6 in. centres, and with a 1½-in. pipe down the centre, emerging in the shoe through which water was pumped during driving at a pressure of 250 lbs. per sq. in.

The average driving was at about two to three weeks after making, the earliest being at six days. The piles were driven to a set of ⅜ in. for ten blows, mostly with a 47-cwt. steam hammer falling 3 ft. The dead weight is 3 tons per 51-ft. pile and 3½ tons per 56-ft. pile. The average penetration obtained, including about 2 ft. of top sand, was 10 ft. 3 in., varying from 8 ft. 3 in. to 15 ft. 4 in., being mainly in hard, black, sandy clay, leaving an average of 6 ft. to cut off and a further 3 ft. to strip down the bars.

The walings and rakers (part tide work) are 15 in. by 10 in., with four ¾-in. rods



Reconstruction of Boscombe Pier Head.


COUNTY BOROUGH OF BOURNEMOUTH
BOSCOMBE PIER
PROPOSED RECONSTRUCTION IN
RE-INFORCED CONCRETE
DETAIL LONGL SECN
DETAIL CROSS SECN
SECTION OF PILE
BEAM A
BEAM E
CROSS SECTION
LONGITUDINAL SECTION

and ¼-in. binding at 6 in. centres, the underside of the waling being at spring high tide level. Much trouble was experienced from rough seas, the formwork being washed away at one place eight times before concreting could take place.

The columns are 15 in. by 15 in. octagonal, with eight ¾-in. bars and ½-in. spiral binding at 6 in. centres.

The main beams (east and west) are 28 in. deep by 10 in., including the flange and secondary beams; the north and south beams are 24 in. deep by 10 in., including the flange. The span in both cases is 18 ft., designed for a super load of 2 cwt. per sq. ft., to include all dead loads of decking, buildings, etc. A flange 4 in. deep by 18 in. wide is provided to which to bolt the timber joists. The beams have double reinforcement, with six 1⅛-in. bars top and bottom in the main beams, and three 1⅛-in. top and bottom bars in the secondary beams, with ¼-in. binding at 6 in. centres, the shear being taken by bent-up bars.

The top of the beams is 18·04 O.D.—*i.e.*, 15·04 O.D. above spring high tide level—giving a finished deck level 19·50 O.D. in the centre, there being a camber of 6 in. in the 90-ft. width.

An isolated pile just after driving was loaded with 55 tons (150 per cent. load) for two hours, and 100 per cent. load (37 tons) left on for seven days, without subsidence being recorded. Also, on a panel area of beams 36 ft. by 18 ft., 108·5 tons was placed, giving 377 lbs. per ft. super (150 per cent. of super and self load), the average deflection at mid-span of main beams being 0·0081 in., and the total at the centre of the secondary beam, including the 0·0081 in., 0·1365 in.

The concrete throughout was composed of ¾ in. to ¼ in. ballast, 3½ cu. ft.; ¼ in. and less sand, 1¾ cu. ft.; aluminous cement, 1 cu. ft.; giving a 5¼ : 1 mixture, both ballast and sand being dredged from Langstone Harbour. Crushing tests on some hundreds of 3-in. cubes made from different batches from the mixer, gave the following crushing strengths at different ages:

1 day, 3,402 lbs. per sq. in.
2 days, 4,649 lbs. per sq. in.
7 days, 5,734 lbs. per sq. in.
28 days, 6,448 lbs. per sq. in.

as against 600 lbs. per sq. in. working stress permitted by the Ministry of Health.

Serious work was not commenced until April, 1925, and the concrete structure was completed in July, 1926.

The work was designed in the Borough Engineer's office; the contractors for the concrete substructure were Messrs. F. Bevis & Co., of Portsmouth (contract price, £10,250). The contractors for the timber deck and superstructure were Messrs. D. G. Somerville & Co., of Westminster (contract price, £10,780).

The Promenade.—Another reinforced concrete work now in course of construction at Bournemouth is the Boscombe promenade, extending from Boscombe pier eastwards for a length of half a mile. It is of an average width of 54 ft. The promenade consists of a battered sea wall constructed of reinforced concrete, faced with Purbeck stone, 9 in. on bed. The wall is constructed in a series of bays 12 ft. 6 in. centre to centre, with arched concrete backing carried on concrete piers 11 ft. deep by 2 ft. 6 in. thick.

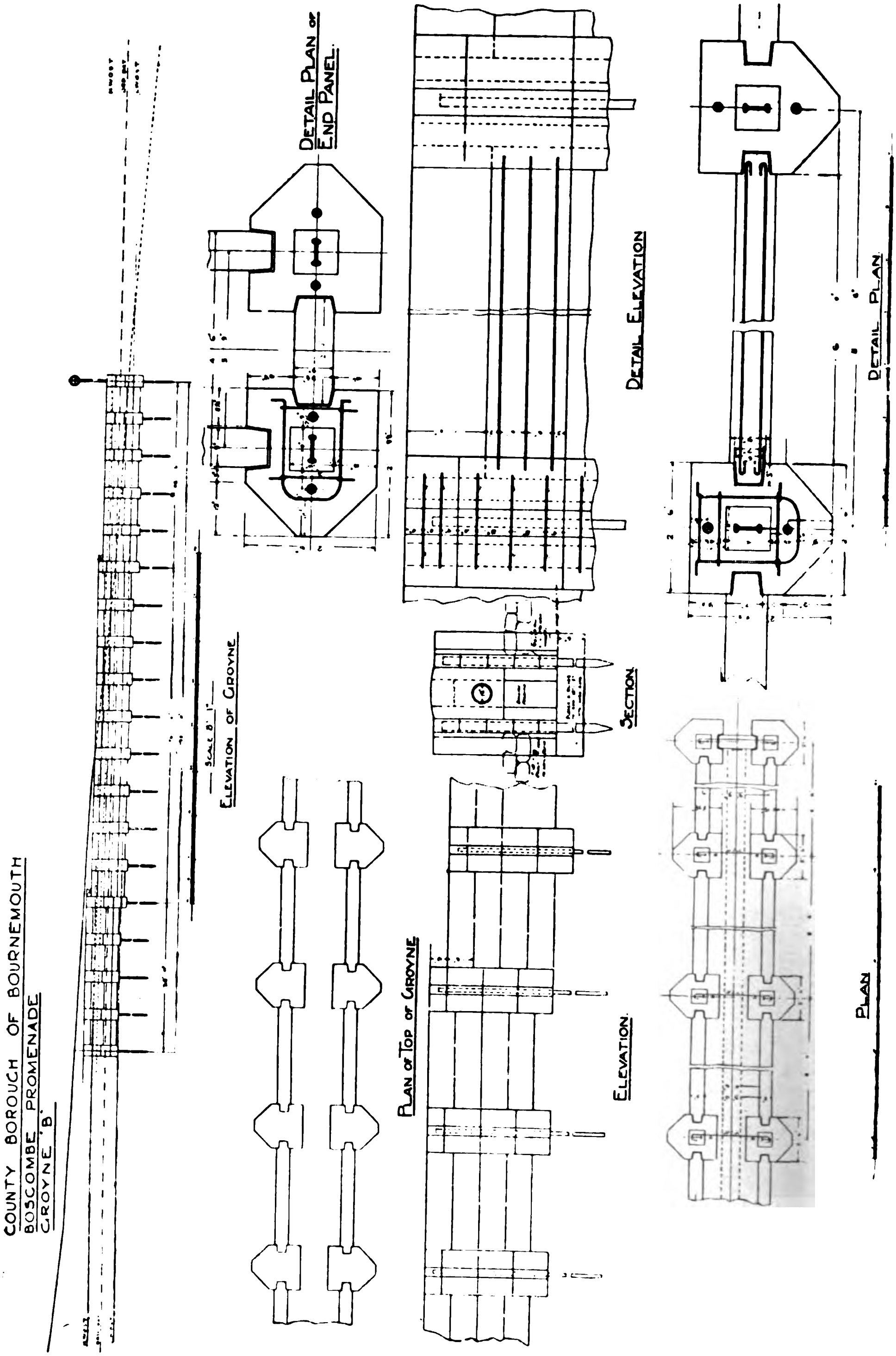
The arched concrete backing is 12 in. thick at the crown, with 9 in. camber, giving 1 ft. 9 in. thickness at springing (piers), and is reinforced with steel mesh. The fabric is wired at the foot to stirrups embedded in the toe of the wall, on the sides to stirrups embedded in the piers, and at the top it is tied into the top beam. This beam, carried by the piers, is 2 ft. 3 in. wide by 1 ft. 3 in. deep, arched in section and reinforced with four ¾-in. indented bars.

The face wall is constructed at an angle of 45 deg., and has a concrete toe 3 ft. wide and 5 ft. 9 in. deep. The toe is carried down approximately 5 ft. into the hard sand or clay to a depth of 6 ft. below O.D. at the west end, and to a depth of 5 ft. below O.D. at the east end. The piers are carried down to a depth of within 12 in. of the foot of the face wall. The sand level varies, and is approximately 4 ft. above O.D.

The pre-cast concrete coping to the wall is 1 ft. 6 in. wide on the top face and 2 ft. 6 in. on bed and 1 ft. 3 in. deep.

At the east end of the promenade a bay 500 ft. long and 50 ft. deep has been cut and shaped in the face of the cliff to form bungalow terraces. These terraces are finished with stone-faced concrete walls. Pre-cast concrete steps lead to them from the promenade. A zig-zag path will be cut to give access from the top of the cliff.

Three different types of groyne are now being employed.


County Borough of Bournemouth
Boscombe Promenade
Groyne 'B'
Scale 8' 1"
Elevation of Groyne
Detail Plan of End Panel
Plan of Top of Groyne
Section
Elevation
Detail Elevation
Detail Plan
Plan

In the first design (*b*) the groyne is 148 ft. long. Seven-inch railway metals are pointed and used as piles, and driven into the hard stratum to a depth of approximately 4 ft. in pairs, 3 ft. 9 in. apart and at 8 ft. 3 in. centres. Pre-cast concrete casings, 2 ft. 6 in. by 2 ft. 6 in. by 2 ft. deep, with 10 in. square hollow centre (reinforced with three light rods), are slipped over these piles, the bottom casings being embedded 12 in. in the hard clay. Two 2-in. diameter W.I. guide rods are passed through the casings, and driven into the hard sand to act as continuous dowels between casings. The bars are fixed across the groyne round piles at each joint in the casings. Pre-cast concrete panels, 6 ft. long by 1 ft. 6 in. deep by 9 in. thick, reinforced with six ⅜-in. steel rods, are placed in the grooves of the casings and jointed. A rough apron wall of Purbeck rubble is packed dry alongside the groyne. The space between panels is filled with 6 to 1 Portland cement concrete for the length of the groyne. The design of this type of groyne is illustrated on p. 810.

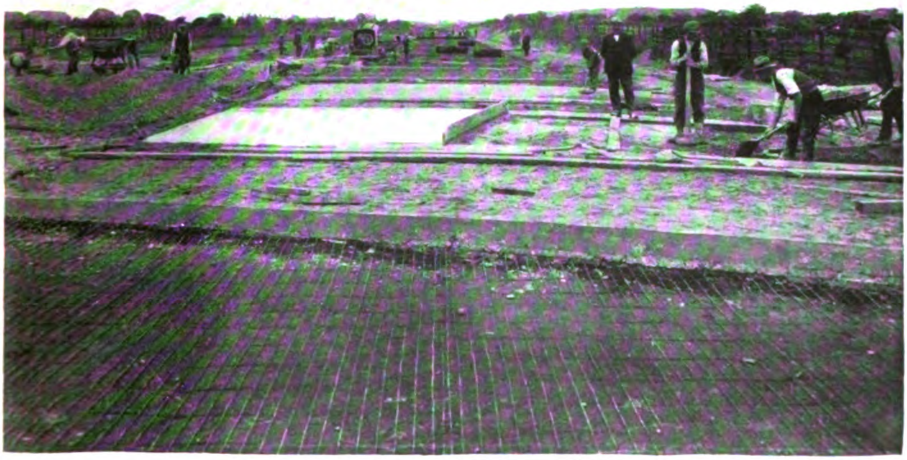
In the new section the finished groyne (*a*) will be 212 ft. long, with piles driven as before in pairs 3 ft. 4 in. apart, but at 4 ft. 3 in. centres. The hard sand is excavated to a depth of 12 in., and pre-cast concrete grooved blocks, 4 ft. 2 in. long by 3 ft. wide by 2 ft. deep, weighing 1·6 tons, are placed in position between the piles. The second grooved block (1·65 tons) is placed on top of the first block to break joint. Sandbags filled with cement mortar 2 to 1 are placed between the two blocks to act as a joggle joint.

The third type of groyne (*c*) is 80 ft. long by 3 ft. wide, with sides slightly battered, constructed in bays of 12 ft. in length in mass concrete (6 to 1) using aluminous cement. The hard clay is excavated to a depth of 6 in., and steel plates used as shuttering.

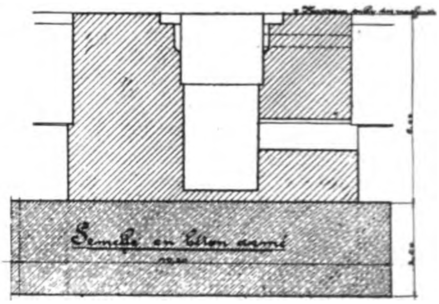
We are indebted to the Institution of Municipal and County Engineers for permission to publish this abstract from a paper read before the Institution by Mr. F. P. Dolamore, F.S.I., Borough Engineer and Surveyor of Bournemouth.

New Concrete Arterial Road.

THE Newcastle–Tynemouth coast road illustrated below is an arterial road carriageway, 30 ft. between kerbs, and is about five miles in length. It is being constructed of 7 in. of concrete, reinforced, and the photograph shows where the B.R.C. fabric is being used. This is a concrete-surface road and is being carried out for following authorities of Newcastle (City Engineer, Mr. W. J. Steele), Tynemouth (Borough Engineer, Mr. J. F. Smillie), Wallsend (Borough Engineer, Mr. J. Blench), and Long Benton (Surveyor, Mr. W. Bean).



Engine Foundations.



Cross-Section of Foundation.

A RECENT article in *Il Costruttore Edile* deals with the design of foundations for engines with unbalanced loads, a problem rather of dynamics than of statics. The design in question is for the foundation of a central station gas engine which is supported by 153 piles of the Franki type in reinforced concrete supporting a footing slab 8 ft. 3 in. thick, on which the superstructure of the foundation is built. Each pile sustains a load of 37 tons. The maximum vertical load on the 153 piles is composed as follows:

	tons.
Weight of engine	570·00
Unbalanced centrifugal forces . .	44·85
Weight of superstructure of foundation	3,000·00
Weight of footing slab	2,041·05
Total	=5,655·90

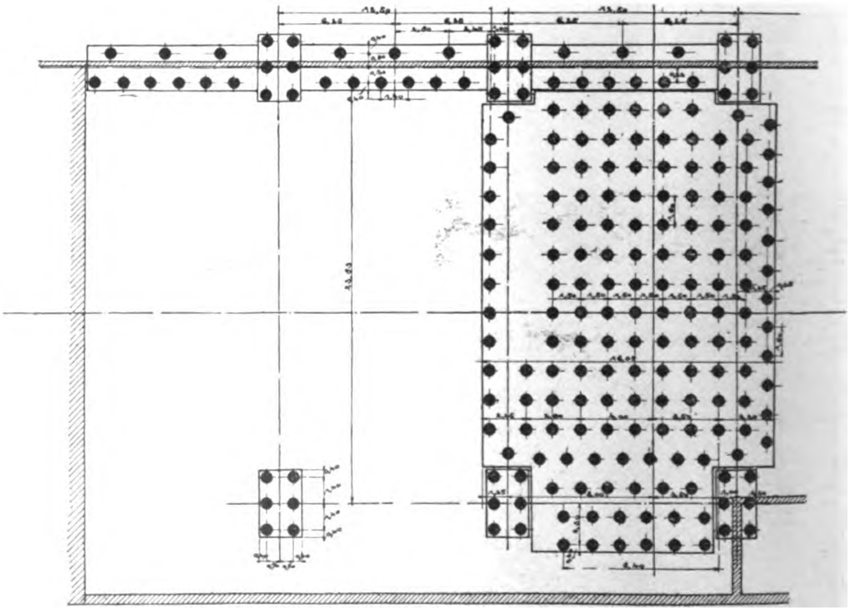
The theoretical free movement of the total mass is

$$\frac{34{\cdot}13 \times 750 - 4{\cdot}56 \times 1{,}000}{541{\cdot}9 + 5{,}041{\cdot}05} = 3{\cdot}8 \text{ mm.}$$

Where 34·13 tons = wt. of parts moving in a horizontal straight line
750 mm. = radius of centre of gravity of these parts
4·56 tons = unbalanced weight
1,000 mm. = radius of centre of gravity of this weight
541·9 tons = wt. of fixed parts of engine.

The movement of 3·8 mm. is resisted by (1) ground friction, (2) end thrust of the earth, (3) shear in pile bars, and (4) shear in pile concrete.

As it is impossible to take into account



Piling Plan.

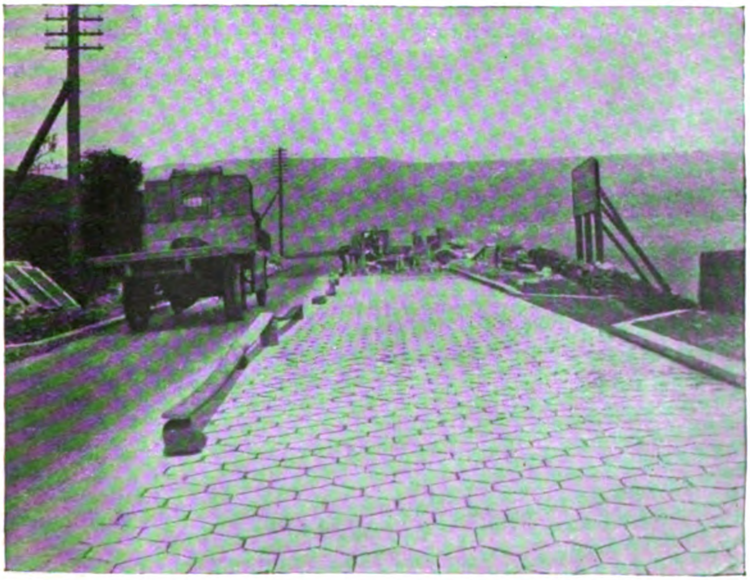
the combined effect of these resistances they are computed separately—giving a factor of safety against the action of the first two of 7·4 and of 12·4 against shearing. To agree with Wohler's Law these factors of safety ought to be multiplied by one-half.

The illustrations show the piling plan for one engine and a cross-section of the foundation.—W. S. G.

Concrete Roads.

An excellent exposition of the advantages of all-concrete roads has been issued, in the form of a booklet, by the British Portland Cement Association, Ltd. Examples are given of this type of road laid as far back as 1873, and still giving good service in spite of the lack of knowledge of the right materials and methods of concrete road construction fifty years ago. We learn that at the end of June this year there were 1,824 all-concrete roads in Great Britain, with a total area of about five million square yards. The booklet does not attempt to give details as to methods of construction, but is confined to illustrations of typical concrete roads and the claims of this type of road from the points of view of economy in first cost, maintenance, and durability.

We illustrate below a photograph from this publication showing the "Hexacrete" system of hexagonal block roads patented by Mr. J. E. Cardell, A.M.Inst.C.E., Divisional Surveyor of the West Riding of Yorkshire County Council. The blocks are provided with grooves on the underside for the reception of steel bar reinforcement, which is held in position and firmly united to the blocks by cement mortar, the whole—the blocks and the reinforcement—being bedded on cement mortar. The blocks are compacted by hydraulic pressure and matured before being put into use. A section some 2,000 square yards in area has been paved with these blocks on the main road near Standedge in the West Riding of Yorkshire. This road forms part of the trunk route from Liverpool, via Manchester and Leeds, to Hull, and the traffic census at the nearest census point gave a tonnage of some 5,000 tons per day. So far, it is stated, no perceptible effect has been produced upon it, even by steel-tyred bogies carrying heavy boilers.



Hexagonal Block Road near Standedge.

Book Reviews.

"Consistence of Cement Pastes, Mortars, and Concrete." By N. Dowey, B.Sc., A.M.Inst.C.E.

London: H.M. Stationery Office, Price 2s. net.

A RÉSUMÉ of this publication of the Building Research Board of the Department of Scientific and Industrial Research formed the subject of an article by Mr. Davey in our issue for October. The objects of the investigations were (1) to investigate what factors affect consistence, besides the most obvious one—the percentage of water; (2) to investigate the effect on strength of each of these factors; and (3) to investigate various methods of measuring consistence, and to find which of these is most suitable for the ranges required both for practical work and for laboratory work. The author shows that various factors are involved and that for an ideal specification, in addition to consistence, such factors as method and time of mixing should be specified. The consistence of the mix and also the strength of the resulting product depend on these factors. In an introduction, the Director of Building Research states: "Whilst it is not considered that finality has been reached, it is hoped that the data here collected may help to draw attention to the importance of the subject both from the standpoint of the amount of water to be used in practice and also that to be used in laboratory testing."

Cemento Armato, Teoria e Pratica. By Ing. Adriano Bagnasco.

Second edition. Brescia: G. Vannini. Price L30.

THE new edition of this Italian book on the theory and practice of reinforced concrete has been issued in order to bring it up to date. There has been considerable revision and enlargement together with the addition, in an appendix, of the new Government regulations for concrete work which are now in force in Italy.

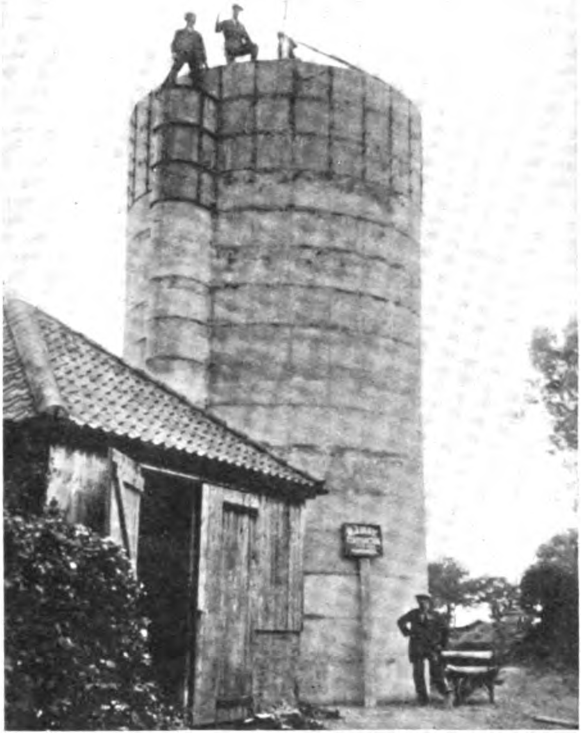
The book is divided into three parts, namely, execution of work, design, and the application of reinforced concrete. The first part deals with (*a*) the properties of cement, sand and aggregate and the proper proportion of water to use in mixing concrete, (*b*) bending and fixing steel reinforcement, and (*c*) mixing, mixers and formwork.

The section devoted to design is based on a ratio of $E_s \div E_c = 10$, which is usual in Italian practice. Long columns (that is, when $\frac{l}{d} > 15$) are designed by means of a formula based on that of Rankine, and a table is given of radii of gyration for different columns. In the design of shear reinforcement the method of inclined compressions is mentioned but not very fully explained. Square slabs have more space devoted to them than is usual in books of this type, the methods of Bach, Grashof and Professor Danusso being all explained at length. The amount of space set apart for monolithic constructions is rather small, but a considerable number of references to the work of Magnel, etc., will be of help to readers.

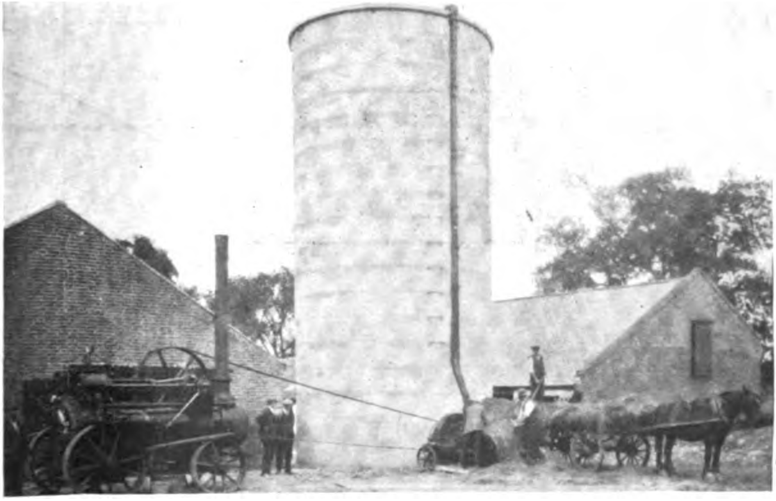
The third part of the book contains a number of designs worked out for various structures. The detail drawings in this part will be useful to designers.—W. S. G.

Concrete Silos in Norfolk.

ON p. 815 we illustrate two silos recently erected at Norwich. The silo illustrated in the lower photograph is at Whitlingham Sewage Farm; it is 40 ft. high by 16 ft. in diameter, with a flat roof and 6-in. reinforced concrete walls built with "Metaform" steel forms. The silo at Holverston is of similar construction. It is of interest to note that the Engineer to the Norwich Corporation inspected several types of silo before deciding that reinforced concrete was the best and most economical material.



Concrete Silo at Holverston, Norwich.



Concrete Silo at Norwich for Norwich Corporation.

Concrete Silos in Norfolk. (*See p.* 814.)

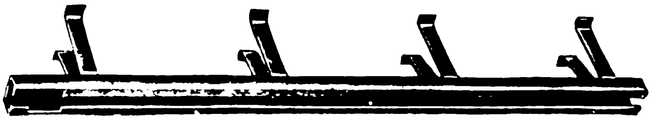
Fixing Machinery to Concrete.

GREAT strength is one of the chief properties of concrete, and valuable as this is in ensuring a long life for a building, it is apt to be a source of difficulty when alterations are required which entail cutting away. This is particularly the case in factories where shafting has to be fixed to the concrete at a number of points in the first instance and perhaps changed later to allow for a rearrangement of plant.

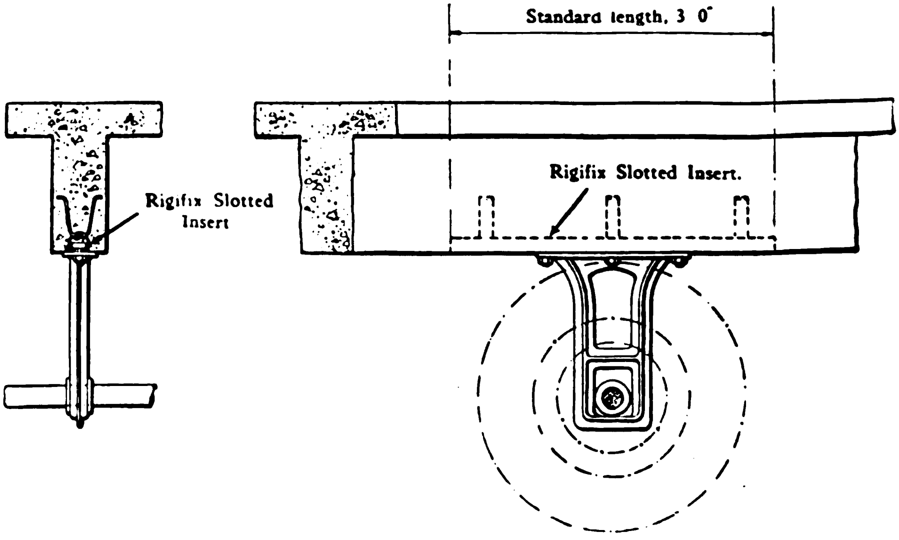
Mobility of plant governs the efficiency of the lay-out of a factory, for until the factory is complete it is almost an impossibility to fix finally the position of each and every piece of machinery. Even if this were possible, alterations and expansion usually involve a general reshuffling of plant, and provision for this should be made when the building is erected.

To provide adequate fixings to cover all eventualities and rearrangement of shafting, etc., is, therefore, essential. Many are the objections to the old method of cutting and dowelling concrete. From the owner's point of view dowelling is never secure, it takes a long time, makes a mess, and is expensive. The engineer objects to it because whereas many places can be chosen without any detriment to the construction a free hand given to shaft fixers and electricians has often led to difficulties. The contractor dislikes it as it means going back on his work and spoiling the finished appearance, and the workmen loathe it because there are few more thankless tasks than cutting into reinforced concrete.

Bolt hanger sockets enable standard Whitworth thread bolts to be screwed into the concrete work. The standard size, to take a ¾-in. bolt, will support a suspended load of 1 ton from each socket. A special size, for a ⅞-in. bolt, will support 1½ tons. Such a socket can be used only where the concrete is deep, as in beams



Slotted Insert.



Slotted Insert Embedded in Concrete Beam.

Bolt-Hanger Socket.

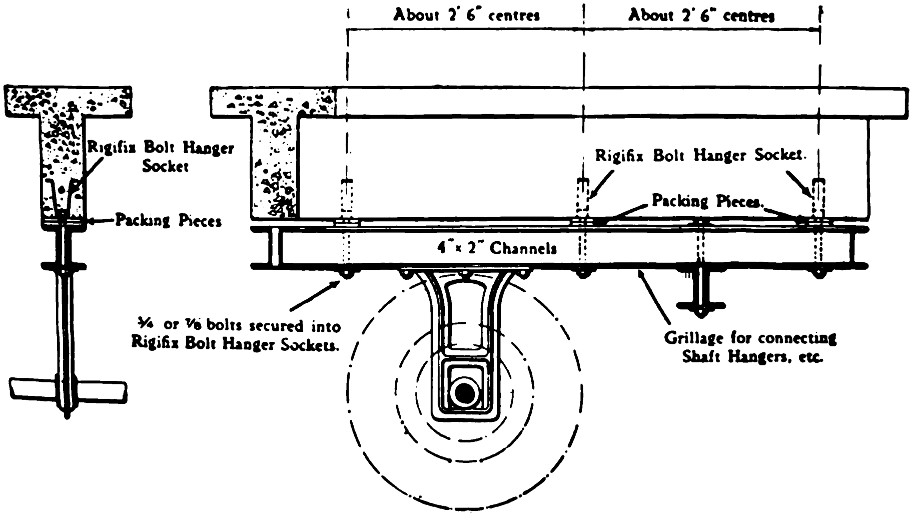
and column sides. A shallow socket is made specially suited for embedding in walls and floor slabs where the depth of concrete is slight.

The slotted insert, embedded in beams, columns or walls, is of value wherever it is not possible to fix beforehand the exact position of the equipment. Its use also eliminates the necessity for an overhead grillage to support the shafting (as shaft-hangers can be attached direct to the concrete beams in which these inserts are embedded) and results in a gain of headroom equal to the depth of the grillage otherwise necessary.

Most factories have a certain amount of overhead shafting and other running gear, and every engineer with millwright experience knows well how greatly the mechanical efficiency of shafting depends on its perfect alignment. Bad alignment is very wasteful of power in frictional loss, and this question of frictional loss is so well understood that all sorts of devices are employed to reduce it, from ball bearings down to the unbushed cast-iron plummer block. But be the bearing ever so efficient, the object is largely defeated when the shafting gets out of perfect alignment.

Fixing these fittings presents no difficulty. Bolt hanger sockets should be fixed to the centering before the concrete is poured by means of temporary bolts let into the centering at the points where the fittings are to be set. Slotted inserts should be laid in the centering in the position where they are to be set and held firmly in place by bolts.

The fittings (which are supplied by Messrs. Huntley & Sparks, of 44/46 King's Road, London, S.W.3) and the method of fixing to the concrete are clearly shown in the accompanying illustrations.

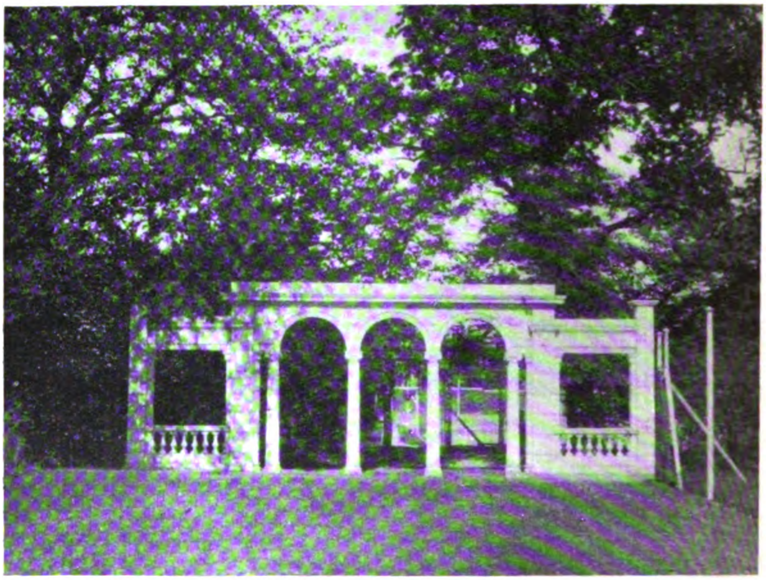

About 2' 6" centres
About 2' 6" centres
Rigifix Bolt Hanger Socket
Packing Pieces
Rigifix Bolt Hanger Socket.
Packing Pieces.
4" x 2" Channels
¾ or ⅞ bolts secured into Rigifix Bolt Hanger Sockets.
Grillage for connecting Shaft Hangers, etc.

Bolt-Hanger Sockets Embedded in Concrete Beam.

Cast-Stone Screen.

THE cast stone screen illustrated was made by the Wharf Lane Concrete Co., Ltd., of Ilminster, to the design of Mr. Colthurst, architect, of Bridgwater. The faces are made of crushed Doulting stone, mixed with Portland cement coloured to match in the proportion of 3 to 1. The backing is of 4 to 1 gravel concrete. The arched portion was formed in a wood mould, filled from the top. The cornice was also cast in wood moulds. The columns, which are reinforced, were cast in a steel mould. Plaster and cement moulds were used for casting the capitals and bases.

After being exhibited at the British Empire Exhibition, the Ideal Home Exhibition and the Royal Agricultural Show, the screen has now found a resting-place on the Portland Sports Club's ground at Snaresbrook. The finely tooled surfaces show no signs of damage as a result of the many times the screen has been removed.



Screen in Doulting Stone Concrete.

DATA FOR PRICING REINFORCED CONCRETE.*

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS.

		s.	d
Best Washed Sand	per yard	16	0
Clean Shingle, ¾ in. mesh	„	14	0
„ „ ½ in. mesh	„	15	6
Thames ballast	„	10	6
Broken brick (¾ in.)	„	11	6
Best British Portland Cement	per ton 68s. to	73	6
"Ferrocrete" Rapid-Hardening Portland Cement	delivered London 10s. per ton extra		
"Super-Cement"	per ton 88s. to	93	0
"Lightning" Brand Aluminous Cement	„ 110s. to	115	6
Ciment Fondu	works f.o.r.	95	0

Boarding for Shuttering—

		Sawn. s.	Sawn. d.	Wrot. s.	Wrot. d.
1 in.	per square	23	6	27	6
1¼ in.	„	29	6	33	6
1½ in.	„	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £22 per standard
3 in. by 6 in. and 3 in. by 7 in.	„ £20 „ „

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt.	10	6
7/16 in. to ½ in. Rounds	„	10	9
⅜ in. Rounds	„	11	0
¼ in. Rounds	„	12	0

Breeze Slabs per yd. super: 2 in., 1/11; 2½ in., 2/4; 3 in., 2/9; 4 in., 3/6.

MATERIAL AND LABOUR, INCLUDING 10 PER CENT. PROFIT.

(*Based on Contracts up to £2,000.*)

Portland Cement Concrete well mixed in proportion 1 : 2 : 4—

		s.	d.
Do do. in foundation	per foot cube	2	3
Do. do. in columns	„ „	2	4
Do. do. in beams	„ „	2	7
Do. do. in floor slabs 4 in. thick	per yard super	7	2
Do. do. in floor slabs 5 in. thick	„ „	8	6
Do. do. in floor slabs 6 in. thick	„ „	10	8
Do. do. in floor slabs 7 in. thick	„ „	11	8
Do. do. in walls 6 in. thick	„ „	10	4

(*Add for hoisting* 3s. 6*d. per yard cube above ground-floor level. Add for "Ferrocrete"* 1s. 10*d. per yard cube.*)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt.	22	6
„ 7/16 in. to ½ in.	„	21	6
„ ⅝ in. to 2⅞ in.	„	20	6

EXTRA LABOUR TO BENDS in ¼-in. rods, ½*d.*; ⅜-in. rods, 1*d.*; ½-in. rods, 1¼*d.*; ⅝-in. rods, 1½*d.*; ¾-in. rods, 1¾*d.*; ⅞-in. rods, 2*d.*; 1-in. rods, 2¼*d.*; 1⅛-in. rods, 3*d.*; 1¼-in. rods, 3½*d.* (per bend per cwt.).

EXTRA LABOUR TO HOOK BENDS: ¼ in., 1*d.*; ⅜ in., 2*d.*; ½ in., 2½*d.*; ⅝ in., 3*d.*; ¾ in., 3½*d.*; ⅞ in., 4*d.*; 1 in., 4½*d.*; 1⅛ in., 6*d.*; 1¼ in., 7*d.* (per bend per cwt.).

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	59	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	55	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11½
Do. do. as last, in narrow widths	„ „	1	1½
Do. do. to sides and soffits of beams, average 9 in. by 12 in.	„ „	1	1½
Do. do. as last, in narrow widths	„ „	1	3½
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	„ „	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	„ „	0	3

WAGES.—The rates of wages on which the above prices are based are:—Carpenters and joiners, 1/9½ per hour; Carpenters working on old shuttering, 1/10½; Labourers on building works, 1/4½; Men on mixers and hoists, 1/5½; Bar-benders, 1/5½.

[* This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

Prospective New Concrete Work.

ABERCARN.—*Houses.*—The U.D.C. has applied for permission to borrow £99,800 for the construction of 192 houses at Llanfach.

ACKWORTH.—*Houses.*—The Hemsworth R.D.C. has been recommended to purchase nine acres of land in Station Road for housing purposes.

AMESBURY.—*Houses.*—The R.D.C. has submitted a scheme to the M.H. for the construction of 30 houses at Amesbury and 28 houses at Durrington.

BELFAST.—*Chute.*—The Corporation proposes to erect a reinforced concrete chute at the pumping station for the new sewerage scheme.

BILLINGHAM.—*Houses.*—The U.D.C. proposes to build 166 houses in Belasis Lane and 58 in Chilton Lane.

BLACKROCK, IRELAND.—*Concrete Footpaths.*—The U.D.C. proposes to spend £3,676 on the construction of concrete footpaths.

BRADFORD-ON-AVON.—*Houses.*—The U.D.C. proposes to build 32 houses on land adjoining Trowbridge Road.

BRANSTY.—*Houses.*—The Whitehaven R.D.C. has made application for permission to borrow £57,500 for a housing scheme at Bransty.

BRISTOL.—*Roads.*—Application has been made for sanction to borrow £25,210 for the construction of roads in connection with the housing scheme at St. Anne's.

CARDIFF.—*Bridge.*—The T.C. has been recommended to erect a bridge over the canal from Hayes to Hill's Terrace. The cost is estimated at £2,500.

CHELTENHAM.—*Road.*—A road is to be constructed off Old Bath Road.

CHESHUNT.—*Houses.*—The U.D.C. has made application for sanction to borrow £15,500 for the construction of 23 houses on the St. Paul's housing estate.

CLACTON.—*Houses.*—The Surveyor has been instructed to prepare a scheme for the erection of 82 houses at Great Clacton.

CLECKHEATON.—*Houses.*—The Spenborough U.D.C. has given instructions for plans to be prepared for the erection of 120 houses.

CLIGERRAN.—*Road.*—The Pembroke C.C. is recommended to make provision for the construction of a road between Cligerran and Llechryd. The cost is estimated at £5,000.

CORK.—*Concrete Roads.*—The County Council proposes to spend £85,000 on the construction of concrete roads.

COVENTRY.—*Road.*—The Corporation is considering a scheme to construct a by-pass road, estimated to cost £150,000.

CROMPTON.—*Houses.*—The Housing Sub-Committee is investigating a proposal to erect 80 houses by direct labour.

DERBY.—*Reservoirs.*—The Corporation is promoting a Bill empowering it to construct service reservoirs at Littleover, Spondon, and Quarndon. The cost is estimated at £160,000.

FAREHAM.—*Houses.*—The R.D.C. proposes to erect 200 houses in the surrounding parishes.

FELLING.—*Houses.*—Application has been made for permission to erect 100 houses on the Bogg housing estate.

FLEETWOOD.—*Defence Work.*—The U.D.C. proposes to erect groynes on the foreshore near the Marine Gardens, and to build a reinforced concrete wall and slipway adjoining the Low Level Promenade.

GREENWICH (LONDON).—*Jetty.*—The B.C. recommends the borrowing of £17,900 for the construction of a reinforced concrete jetty.

HARTLEY WINTNEY.—*Houses.*—The R.D.C. has decided to erect 100 houses in the surrounding parishes.

JARROW.—*Road.*—The Town Improvement Committee has instructed the Borough Engineer to prepare plans for the construction of a road from Church Bank to meet the new Don Bridge.

KENDAL.—*Houses.*—The Housing Committee has been instructed to prepare a scheme for the erection of 100 houses.

LEEDS.—*Reservoirs.*—The T.C. proposes to construct a reinforced concrete reservoir at Tinshill, and to extend the Middleton reservoir to a capacity of 1½ million gallons.

LLANGOLLEN.—*Reservoir.*—The R.D.C. is considering plans and cost of constructing a reservoir at Llangollen.

LOUGHBOROUGH.—*Houses.*—The Corporation has purchased Skelthorpe Farm, on which to build 100 houses.

MERTON.—*Houses.*—The Merton & Morden U.D.C. has decided to erect 100 houses at Cannon Hill and Whatley Avenue.

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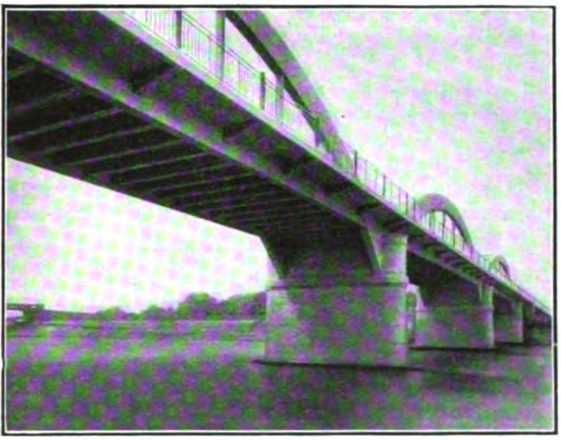

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NEWPORT (MON.).—*Houses.*—the T.C. has been recommended to purchase a site in Commercial Road, on which to erect 120 houses.

OMAGH.—*Concrete Road.*—The Omagh U.D.C. proposes to borrow £10,000 for construction work, which will include the laying of about a half-mile of reinforced concrete roadway.

ORSETT.—*Houses.*—The R.D.C. has applied for sanction to erect 200 houses in the rural area.

PETERBOROUGH. —*Houses.* —The T.C. has applied for sanction to borrow £33,110 for the construction of 77 houses.

PLYMOUTH.—*Houses.*—The Admiralty is to erect 200 houses at Plymouth for the dockyard employees.

POOLE.—*Concrete Pavilion.*—The T.C. is considering a scheme for the construction of a reinforced concrete pavilion.

POOLE.—*Road.*—A road is to be constructed from Baiter to Whitecliff.

PRESCOT. —*Road.* —The Corporation Finance Committee is considering the cost of constructing a road near the present College Road.

RAWTENSHALL. —*Houses.* —The T.C. has applied for permission to borrow £32,870 for the erection of 54 houses on the Oakley estate.

REDDITCH.—*Houses.*—The U.D.C. has applied to the M.H. for sanction to borrow £18,000 for the erection of 40 houses on Beoley Road.

SOUTHPORT.—*Bathing Lake.*—The Corporation proposes to spend £60,000 on the construction of a bathing lake.

STARE. —*Bridge.* —The Warwickshire C.C. has appointed a sub-committee to report upon a proposed scheme to replace the existing Stare Bridge. The cost is estimated at £13,250.

STOCKINGFORD.—*Houses.*—The Nuneaton T.C. has instructed the Borough Architect to prepare plans for the construction of 40 houses in Hill and Short Streets.

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TAUNTON.—*Concrete Houses.*—The T.C. proposes to build 100 concrete houses in Lambrook Road.

THORNE.—*Bridge.*—The West Riding C.C. proposes to construct a bridge across the Dutch River at Thorne.

THORNHILL.—*Houses.*—The Dewsbury T.C. has instructed the Surveyor to prepare plans for the erection of 65 houses at Thornhill.

TOTTENHAM (LONDON).—*Bridge.*—The Gas Company proposes to build a bridge over the level crossing near the Company's works.

WATERFORD.—*Harbour Improvement.*—The T.C. proposes to spend £50,500 on improvement to the harbour.

WELLINGBOROUGH. — *Houses.* — The Surveyor has been instructed to prepare plans for the erection of 100 houses on land between Elsdon and Finedon Roads.

WINLATON. —*Houses.* —The Blaydon Council has applied for sanction to erect 90 houses at Black Green, near Winlaton.

Tenders Accepted.

GLASGOW.—The T.C. has accepted the tender of Messrs. A. M. Cochran & Co., at £2,818 3*s.* 8*d.*, for the construction of reinforced concrete supports for strengthening the north wall of No. 3 coal store at the Dawsholm Gasworks.

LONDON (CAMBERWELL).—*Concrete Paving.*—The B.C. has recommended for acceptance the tender of Mr. A. L. Etheridge, Rollins Street, S.E., at £294 4*s.* 8*d.*, for paving Artichoke Mews with concrete. Other tenders submitted were: D. E. Etheridge, £295 14*s*. 2*d*.; E. J. Harris & Co., Ltd., £312 10*s*. 10*d*.; H. Woodham & Sons, £329 5*s*.; Walker-Weston Co., Ltd., £333 15*s*.; W. H. Wheeler & Co., Ltd.; £339 3*s*. 4*d*.; F. R. Hipperson, £455 16*s*. 4*d*.; W. Peters, Ltd., £461.

LONDONDERRY.—*Concrete Wharf.*—The Port & Harbour Commissioners have accepted the tender of Mr. R. Colhoun, Londonderry, for the construction of a 400-ft. reinforced concrete wharf at Queen's Quay.

LIVERPOOL.—*Wall.*—The Corporation has accepted the tender of Messrs. Morrision & Sons, Wavertree, at £2,211, for the construction of a reinforced concrete wall at the police station in Everton Terrace.

MARCH.—*Bridge.*—The Ely C.C. has accepted the tender of Messrs. H. Rands & Son, Wisbech, at £2,577 7*s*. 4*d*., for the demolition of two bridges and the construction of a concrete tunnel at Wisbech Canal.

MIDDLETON.—*Concrete Bridge.*—The Laurencekirk D.C. has accepted the tender of Mr. A. Adamson, Laurencekirk, at £386, for the erection of a reinforced concrete bridge at Middleton. Other tenders submitted were: W. J. Anderson, £497 8*s*. 4*d*.; W. Tawse, Ltd., £468 18*s*. 3*d*.; James Scott & Son (Aberdeen), Ltd., £447 11*s*. 2*d*.; Clark & Chapman, £394 8*s*.

WINDSOR.—*Waterworks.*—The T.C. has accepted the tender of Messrs. Concrete Piling, Ltd., at £2,336 15*s*., for work at the waterworks.

Recent Patent Applications.

239,504.—G. J. Fink: Cementitious compositions.
250,950.—A. Schatz: Reinforced concrete masts.
250,980.—J. M. Sargeant: Concrete walls.
258,720.—J. Clements: Concrete walls.
258,727.—P. Budnikoff; Cementitious substances.
258,767.—S. A. Orr and R. Corkey: Reinforced concrete.
258,947.—R. A. Eaton: Concrete block mould-boxes.
259,037.—J. T. McLay: Centering for concrete floors.
259,261.—A. Bates: Concrete buildings.
259,503.—G. E. Heyl: Making cement.

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Trade Notices.

Sand.—We have received from Mr. A. E. Curtis, of Westmoor Laboratory, Chatteris, a catalogue describing the special sands he supplies and their uses. This brochure is more than a catalogue; for the wealth of information it contains from the authoritative pen of Mr. Curtis gives it a distinction not possessed by the usual run of catalogues. Mr. Curtis specialises in the supply of special sands, and does a large business in cement testing sand and sand guarenteed to within 2 per cent fineness. Copies will be sent post free to readers of this journal.

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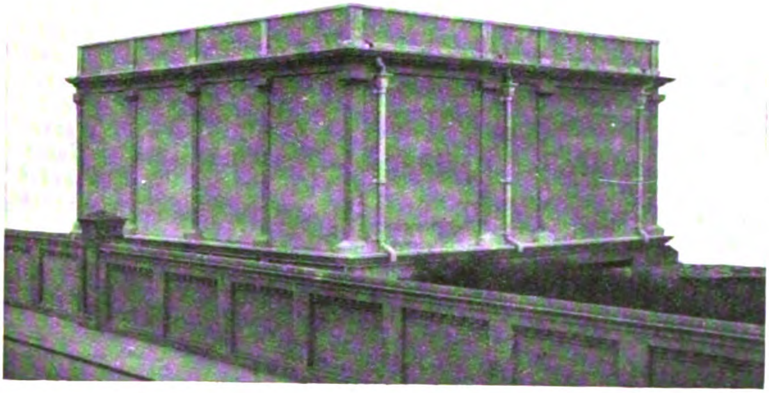

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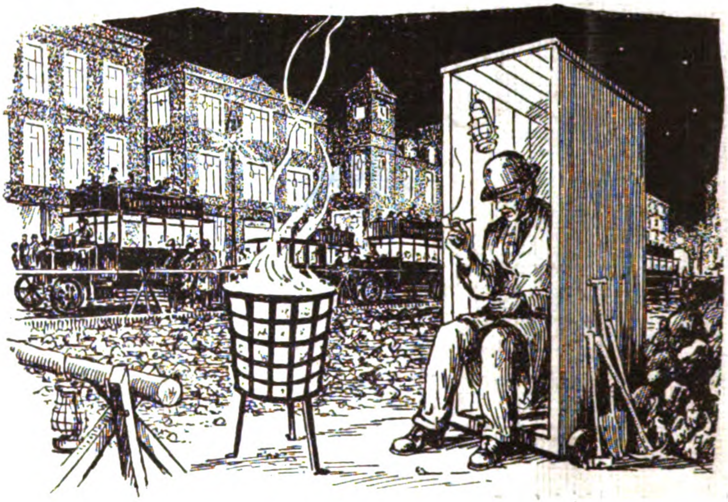

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